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# METALS and ALLOYS

## The Magazine of Metallurgical Engineering

**PRODUCTION • FABRICATION • TREATMENT • APPLICATION**

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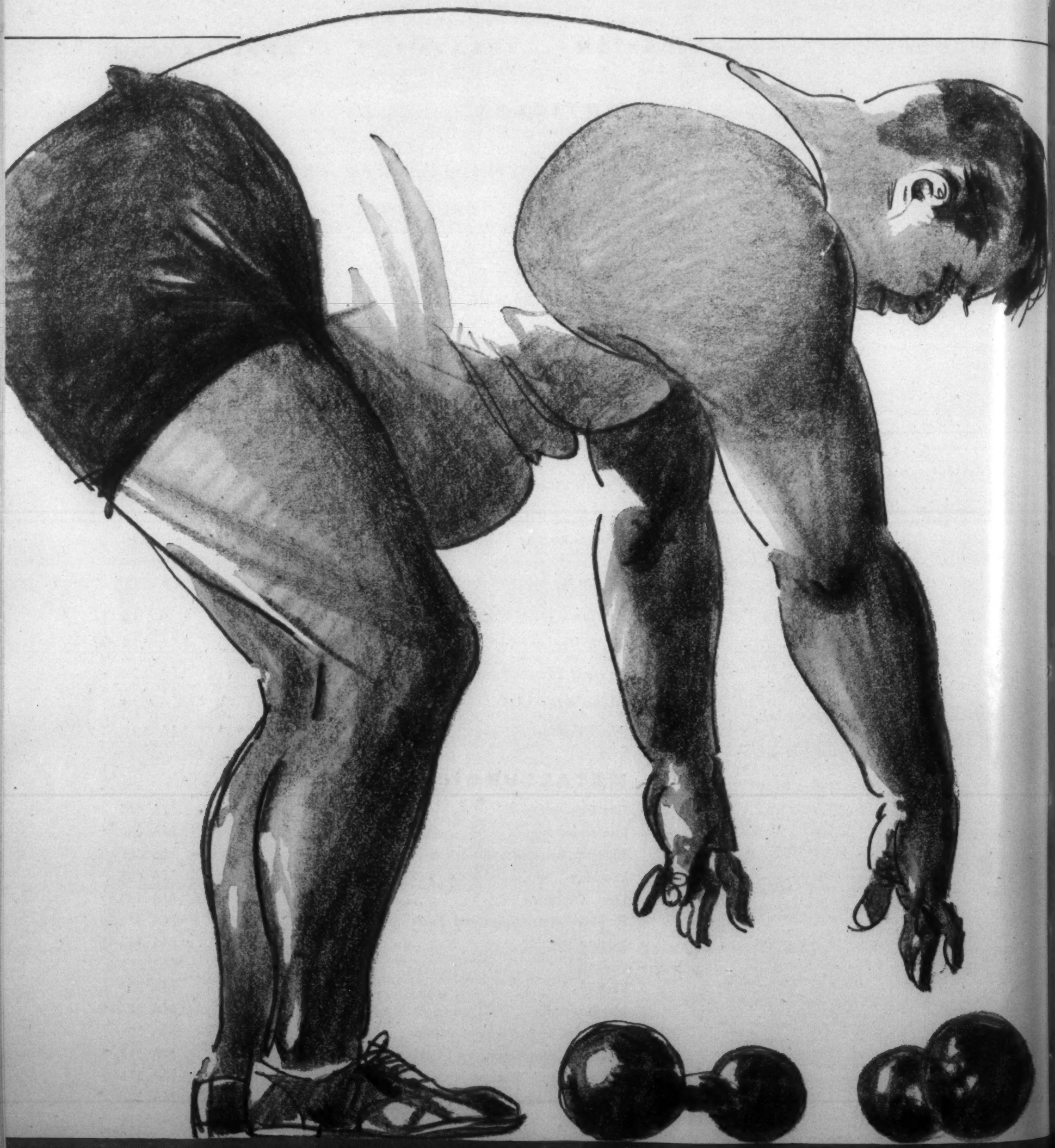


UNITED STATES STEEL

## AN INTERNALLY HEATED

# Electric Salt Bath Furnace

## —SOME USERS' EXPERIENCES

by Fred P. Peters

*Assistant Editor,* METALS AND ALLOYS

PROGRESS IN THE LAST 5 years in the heat treatment and case hardening of steels and in the heating of all metals has been remarkable. New basic methods, improved, mechanized equipment for old methods, widespread attention to "atmospheres" have been outstanding in the general advance. Flame and induction surface hardening, induction and resistance heating, controlled atmospheres for heat treating without oxidation or decarburization, gas carburizing, convected air, recirculating type furnaces, more efficient burners, radiant tube heating, better electric heating elements, automatic temperature control, etc., have all been introduced or widely applied in recent years.

One of the most important of recent developments was the introduction in this country by the Ajax Electric Co., Philadelphia, of the Ajax-Hultgren electric salt bath furnace two years ago. Although there are other electric salt bath furnaces, of somewhat different design, available to-

*One of the Furnaces in Operation at The Bullard Co.*

*One Type of Gear Treated by The Bullard Co. in the Ajax-Hultgren Furnace.*

day, only the Ajax-Hultgren will be discussed in this article. The use of this furnace on a full production scale was first described by Davis,[1] in this magazine, and since that time other articles descriptive of operating installations have been published elsewhere. Among these have been a presentation by Adam[2] of operating details and results obtained with different salts; a discussion by Hultgren[3] of the application of this type of furnace to the heat treatment of high speed steel (the Ajax Electric Co. has recently announced the adaptation of the Ajax-Hultgren principle to the construction of a special furnace for operation up to 2400 deg. F., which can be applied to the hardening of high speed steels); a description by Abbott[4] of the use of the furnace in heat treating automotive parts; a description by Flury[5] of the incorporation of the Ajax-Hultgren furnace in continuous processing; and an outline by von Zeerleder[6] of the use of this furnace in the aluminum industry. In all of these the design, operation and advantages of this type of immersed electrode salt bath furnace have been thoroughly discussed, so that only a brief review of these points need be given here.

## Design and Operation

The Ajax-Hultgren furnaces are usually rectangular units. In the simplest design, the lower portion of a single pair of electrodes is submerged in the salt at the rear of the pot, and alternating current is fed through a step-down transformer. The distance between the electrodes is less than the distance between either electrode and the metal pot, or between the electrodes and the work. With this arrangement, only the salt between the electrodes is heated by the passage of current through it, but the molten salt between the electrodes is rapidly ejected therefrom by the electromagnetic effect, and the resulting vigorous stirring action keeps all portions of the bath constantly flowing in and out of the interelectrode space. Most of the production furnaces have more than one pair of electrodes, depending on the working capacity and temperature desired; but the basic principle remains the same.

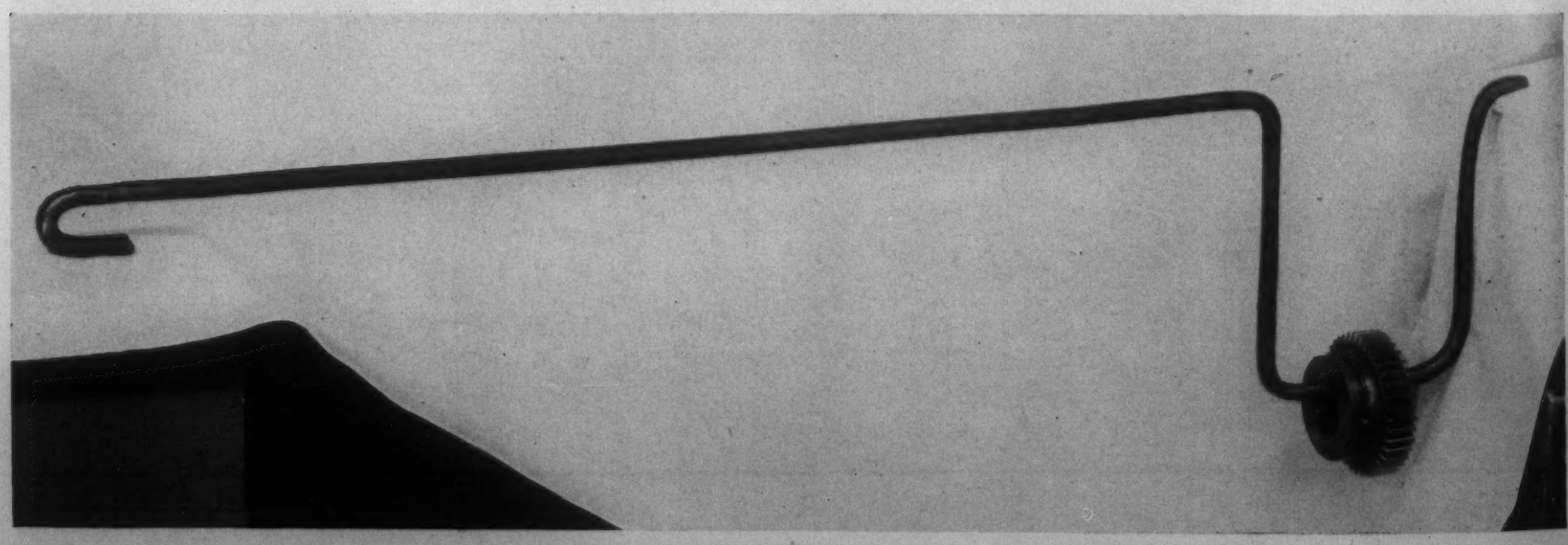
This arrangement of a heating zone distinct and separate from a working zone in the same bath at first suggests something less than uniform heating. The stirring action just mentioned, however, more than offsets the separation effect, and the manufacturer's claim of unusually uniform temperature distribution throughout the bath has been corroborated in every case. Other advantages claimed for the Ajax-Hultgren furnace include longer pot life, because of the internal heating; economical heating, because of the confinement of heat to the inside of the pot; ease and accuracy of control and the attendant improved quality of finished work; and convenience, cleanliness and comfort to the workmen.

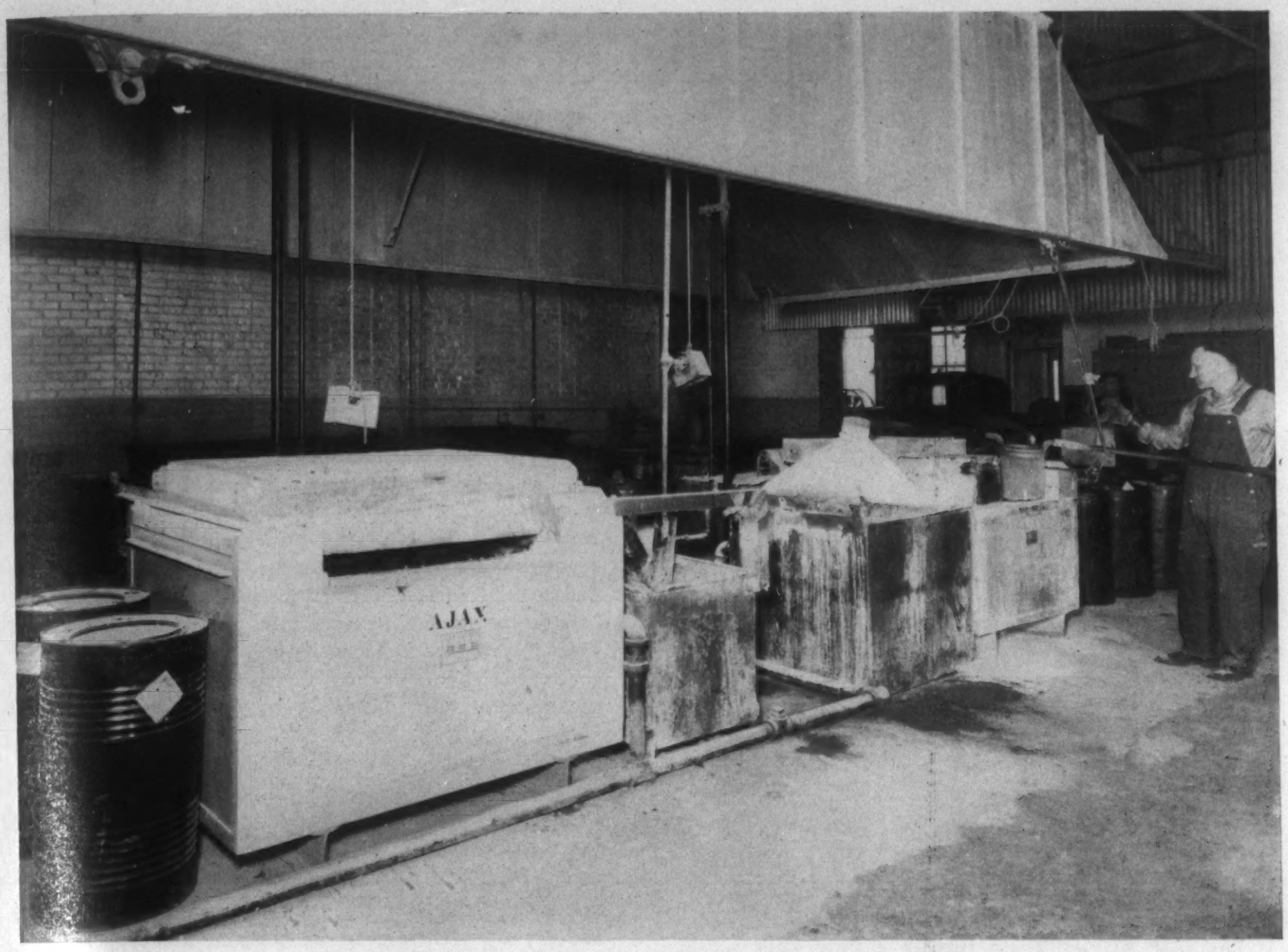
## Practical Experience with the Furnace

An ideal appraisal of the merits of this furnace should provide answers to the skeptic's natural questions: Is pot life really longer, under similar production conditions, than with externally heated pots? Is the heating so economical when the usually higher "fuel" cost of electricity is considered? Is the work turned out by this furnace actually of a higher quality than that produced by older methods? Doesn't this furnace, like most new developments, have a lot of "bugs" still to be exterminated?

The answers to all but one of these questions were found in the experience of three important users of the Ajax-Hultgren furnace. To the question concerning economy of heating no direct, quantitative answer was obtain-

*Method of Suspending Gears in the Salt Bath Furnace at The Bullard Co.*






*Two of the Three Salt Bath Furnaces at The Bassick Co.*

able. The reason for this seems to be that other considerations loomed so much larger than "fuel" economy that no investigation of this factor was made, or because drastic changes in conditions, such as the use of a much larger pot in the electric furnace than in the fuel-fired or a switch from box carburizing to salt bath, made comparison difficult.

In reporting the experience of these users, we will try to include all the operating factors present and to give all the little details with which the men working with, or close to, the furnace, would be concerned. The three companies whose practice was studied were The Bullard Co., Bridgeport, Conn., manufacturers of machine tools; The Bassick Co., Bridgeport, Conn., manufacturers of hardware parts; and a large company in New York who produce engraved certificates, stamps, etc. The complete cooperation given by each of these companies in the preparation of this article is gratefully acknowledged.

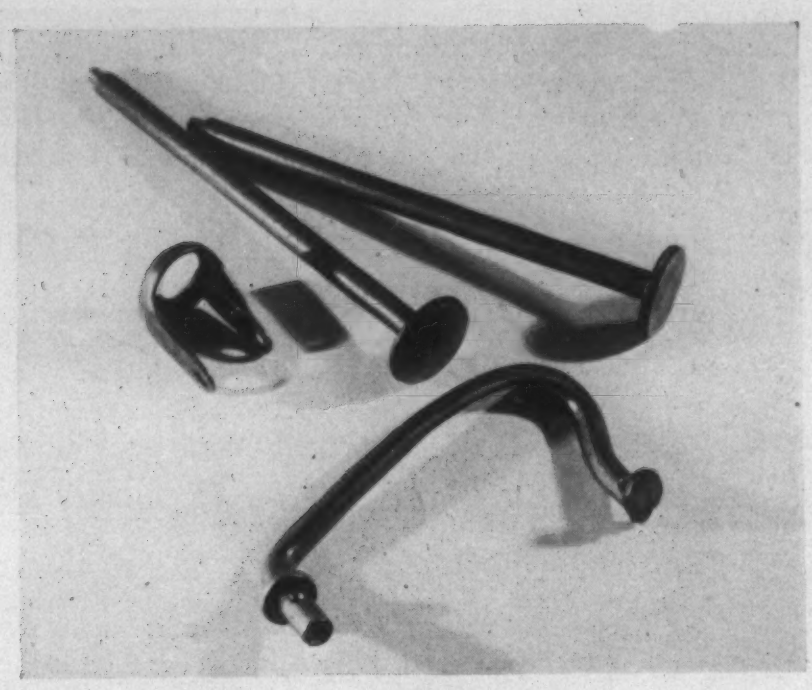
## Hardening Gears in a Liquid Carburizing Bath

Prior to the introduction of two Ajax-Hultgren furnaces for hardening by means of a liquid carburizing bath, The Bullard Company employed an oven-type furnace for heat treating direct-hardening alloy steel gears. In this former method all machining operations were completed before hardening, with the exception of gear cutting, which was performed to full depth in a roughing operation, but left several thousandths (about 0.020 in.) on the sides of the teeth for finish cutting after heat treatment. The machined gears were hardened by oil quenching from the oven-type furnace and subsequently drawn to a hardness which would permit the finishing operation to be performed. Although this method produced a comparatively good gear which surpassed in accuracy a gear finish-cut before hardening or a carburized gear, it was expensive both in cutter life and machining time and did not develop the properties possible with a fully hardened gear.

In order to secure a fully hard yet accurate gear a new method of manufacture was adopted, in which the gears could be cut to within one or two thousandths in one pass on a conventional gear cutting machine such as a hobber or shaper, finished on a gear shaving machine of the crossed axis principle, and then hardened in a carburizing salt bath, followed by lapping on a lapper of the crossed axis principle to remove any distortion resulting from heat treatment.

The Bullard Company has found that the best results are obtained with a steel of S.A.E. 4640 analysis. This is a nickel-molybdenum alloy steel and is ordered with 6 to 8 McQuaid-Ehn grain size. Furthermore, a definite and regular check of material specifications is made in the company laboratory.

The hardening practice found best, after many tests, was heating to 1525 deg. F. in a liquid carburizing bath for 30 min. after coming up to heat, quenching in oil, and draw-



*Some of the Hardware Parts Treated in the Furnaces at The Bassick Co. The two straight pieces at the top are automobile starter-pedal plungers; the bent piece at the bottom is an automobile hood catch handle; the small object at the left is a ball-bearing furniture caster horn.*

ing in a salt bath at 400 to 450 deg. This produces the following physical properties: Tensile 250,850 lbs. per sq. in., yield point 241,200 lbs., elongation 15 per cent in 2 in., reduction in area 2 per cent, surface hardness 64-66 Rockwell "C" (reading taken on superficial tester and converted to C scale) core hardness 53 Rockwell "C".

The first Ajax-Hultgren furnace at this plant was installed in May, 1937, and the second in December. Each furnace has its own air-cooled transformer operating on 440 volts and is rated at 50 kw. Temperature control is maintained by two recording controllers of the potentiometer type. To verify claims made by the Ajax Electric Company in regard to the uniformity of temperature achieved by the automatic stirring action of the bath, a test was made on the first furnace while in operation at 1410 deg. F. The results of 13 temperature readings taken with a new Leeds and Northrup checking potentiometer placed at various positions in the bath yielded two values of 1408 deg. F., the remaining 11 readings being 1410 deg. F.

The pots containing the salt are of welded boiler plate construction, with actual working dimensions 38 in. by 20 in., by 14 in. deep. The salt capacity is 600 to 700 lbs.

Failure of the pot in the first furnace took place after a life of 8680 hrs. This failure appears to have taken place on the outer surface below the level of the bath rather than at the salt inter-face, and seems to have been caused by severe oxidation and scaling of the pot surface adjacent to the furnace lining, weakening the pot at this point to such an extent that it eventually gave way owing to the pressure of the molten salt from within. The electrodes are of alloy iron and were replaced after 8 mos.' service.

The gears to be heat treated are placed in the furnace in such a manner as to utilize the maximum working space, and are suspended in the bath from bars bent in the shape of a crankshaft crank pin, thus giving support both front and rear. The maximum weight of each load is 150 to 200 lbs. The gears are immersed in the salt without preheating. This lowers the temperature of the bath approximately 50 deg. F., depending on the load charged. The bath and work return to temperature in 15 to 30 min. and are kept at heat approximately 30 min. To maintain the strength of the bath, samples are titrated daily and approximately 50 lbs. of used salt are bailed out of each furnace and replaced with new salt.

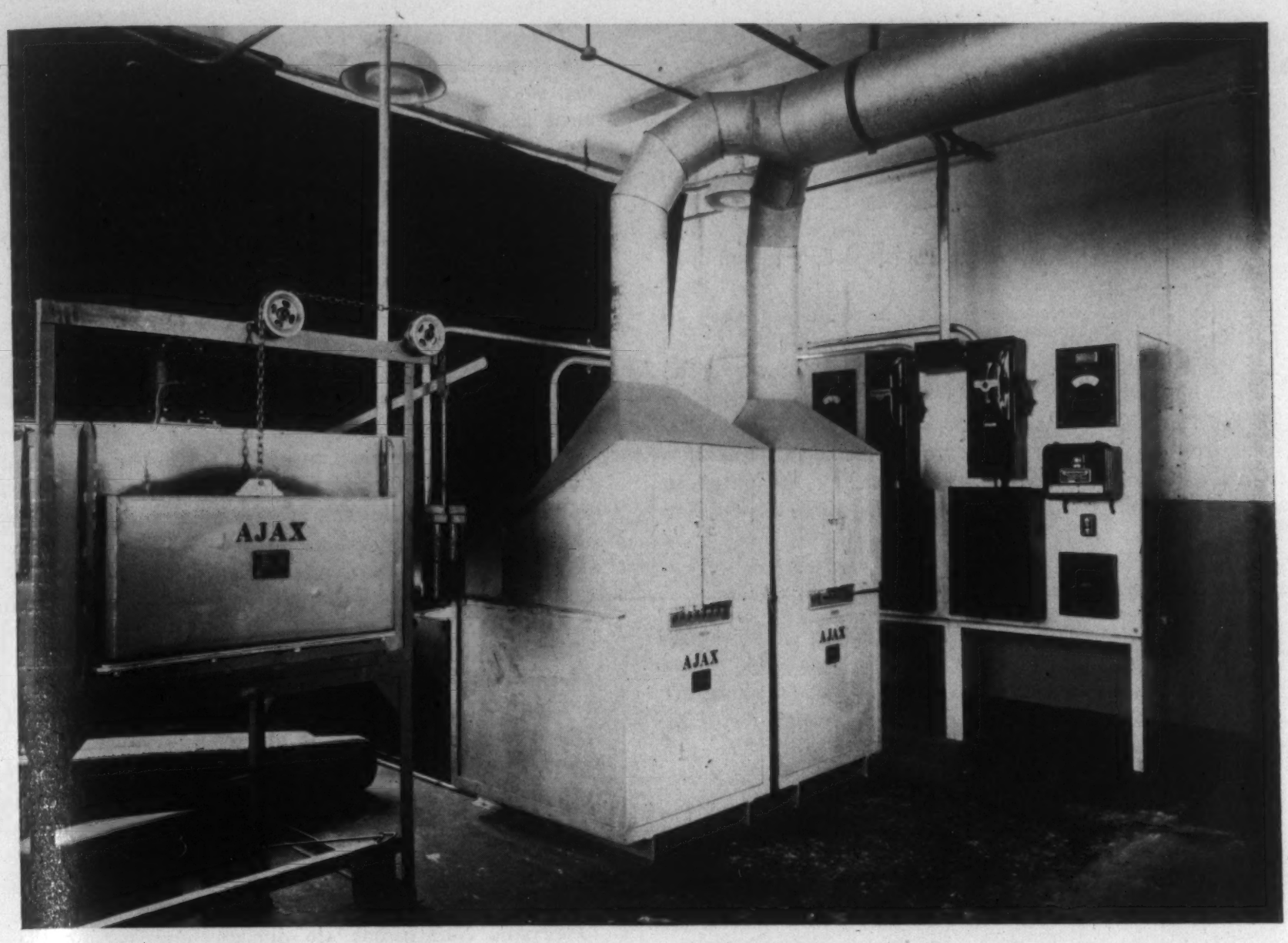
The type of work done in these furnaces is diversified and may be classified as both short and long cycle selective case hardening, as well as heat treating in a neutral bath.

The short cycle hardening treatment consists of immersing the gears in the bath and holding for 30 min. after coming up to heat (1525° F.) and then quenching in oil. This treatment produces a thin hard case of .006 to .008 in. in depth, and applies only to the heavy duty gears made of S.A.E. 4640 steel. Selective case hardening is achieved by copper plating. During the early steel experiments it was discovered that if the entire gear were copper plated with cyanide copper after gear cutting, the subsequent shaving operation would remove the copper from the active tooth profile and thus confine the carburizing action of the bath to this surface, thereby producing an extremely hard case on the wearing surfaces only. The advantage derived from this method is the prevention of any embrittlement at the root of the tooth, since the shaving cutter does not remove any of the stock below the active tooth profile and consequently leaves the surface film of copper as a carburizing stop-off. Subsequent tests have proved that the use of this stop-off very materially increases the root strength of the gear without appreciably altering the hardness of the case.

The long cycle hardening method applies to certain gears made of S.A.E. 1045 steel which require only a hard hole and keyway. These gears are finish-cut and copper plated, after which the hole is ground and the keyway broached, removing the copper stop-off. They are then immersed in the bath for approximately 3 hrs. at 1400 deg. F., producing a case of about 0.016 to 0.018 in. in depth which allows for finish grinding in the hole. This long cycle method has been of inestimable value in producing these gears, since formerly they were quenched in a fixture, losses were exceedingly high and the standard of inspection on these particular parts necessarily very low. The present method has permitted increasing the standard nearly 100 per cent. Even under this critical inspection, rejections rarely occur.

With the introduction of these furnaces, it was found that certain work, which was not intended to be done in salt baths and did not require a case, could be handled with better results in a neutral salt bath than in the oven furnace. Production demanded an activated salt in both furnaces, but, because of the superior quality of the salt bath product, it was decided to copper plate these pieces completely and heat treat them in the activated bath, thereby producing results similar to those achieved in a neutral bath.

The Bullard Company feels that these furnaces have been a very important factor in the success of their new method of handling gears, both from the standpoint of fewer rejections in heat treating owing to non-uniformity of hardness, and fewer rejections from distortion. Owing to the extreme uniformity in temperature throughout the bath, it has been possible to raise the hardness of the gears approximately 4 points on the Rockwell "C" scale, and to place the gears in the bath without regard to hot and cold




*View in the Engraving Company's Heat-Treating Department, Showing Two Small Salt Bath Furnaces and, at the Left, a Forced-Convection Tempering Oven.*

spots. Because of the characteristics of this bath heretofore described, any location in the bath is both effective and reliable. This increase in available working area means the production efficiency of the furnaces is just so much higher.

Additional factors tending toward improved conditions, as compared to the previous equipment, are the ease of operation and the elimination of excessive radiated heat. Naturally, this provides more comfortable working conditions for the operators and other department employees.

## Heat Treating Hardware Parts

The Bassick Company's application of their three Ajax-Hultgren furnaces is featured by its diversity, and indicates the flexibility of the unit for a varied production schedule. Over 5,000 hardware parts are treated daily; most of them are small—in nature they range from automobile starter plungers to tiny door fixtures. The company installed these furnaces to lower their heat treating costs, and to eliminate some very bad working conditions associated with their old fuel-fired pots.

An activated cyanide bath is used in all the furnaces. Some of the parts are given a relatively thick case (0.015-0.020 in.) by 1½ hr. immersion at 1600 deg. F.; others receive a light case by 20 min. immersion at 1550 deg. F.; and a third group are merely treated for "finishing" purposes, being dipped for 3 min. at 1550 deg. F. The stock, which is all low carbon (0.10-0.20 per cent) steel, is water quenched after treatment, without subsequent tempering.

Two of the furnaces are 50 kw. units with working dimensions 36 in. long, 15 in. wide, and 14 in. deep. The third furnace is rated at 35 kw. with working dimensions 24 in. long, 15 in. wide and 14 in. deep. The large furnaces hold 850 lbs. of the salt, and the small furnace, 425 lbs.

Pots are made from welded boiler plate or fire-box steel. The initial cost of these is low, and in addition, pot life has been unusually good. Operating continuously, these welded steel pots in the Ajax-Hultgren furnaces have lasted about 9 months, or around 6500 hrs. In the old externally heated salt baths, pot life as low as 100 hrs. was not unusual. Bassick has had to replace no electrodes, as the original electrodes, even those placed in service in December, 1936, are still operating satisfactorily.

With the large furnace, the transformer starting tap is set to produce a temperature of 1600 deg. F., then lowered to a "running tap" as the salt becomes older and the amperage builds up. When the furnace is started cold with a new salt, full capacity is maintained until the ammeter indicates power consumption at full capacity, after which the voltage is reduced. The molten bath is covered with a layer of plumbago to reduce oxidation and fuming. Depending on their nature, parts are immersed in baskets or on racks. The baskets are of plain C steel wire, except for a peripheral ring at the top, which is made of heat-resistant

alloy. When the basket wire has deteriorated, the alloy ring is removed and placed on a new wire basket.

Bassick's first furnace was installed in October, 1936; the second, in May, 1937; and the third, in July, 1937. Their general satisfaction with this method of heating is therefore evident. The "apparent" cost is greater, but this is because when they started using the new furnaces, they switched to a more expensive salt and lengthened the time cycle for a given job. The control of production and quality is unusually good.

The furnaces were designed to leave an air space all around the pot between the latter and the insulating brick of the furnace shell. When a pot failed salt would run through the hole and fill the air space, necessitating an expensive replacement of the refractory brick. The Bassick Co. corrected this by the simple method of making a small hole through the outer furnace shell at the bottom to allow the molten salt to run on the floor instead of filling the air space.

## Hardening Steel Engravings

A well known company that acts in the capacity of a private bureau of engraving for a number of the world's governments as well as domestic corporations and financial institutions, uses several Ajax-Hultgren furnaces for case hardening and for heat treating parts and equipment used in intaglio printing, *i.e.* steel engravings from which are reproduced bank notes, postage and revenue stamps, bonds, stock certificates and other documents of monetary value. A most important consideration to this company, in all their work, is quality, for the surface of a steel engraving must be perfection itself and the quality of reproduction must be maintained throughout a large number of impressions. The use of the Ajax-Hultgren furnaces is to them, therefore, an important part of their general policy of "quality first."

A large furnace is used almost exclusively for case hardening heavy steel plates; smaller furnaces are used for heat treating die steel in one case and steel rolls in the other. In each instance the hardening is done after the impression has been made on the surface.

The engraver's steel plates case hardened in the large furnace are previously annealed, and the surface tooled; the sides and ends of each plate are electroplated with copper to prevent penetration of the case. Two types of salts have been used at different times: straight sodium cyanide and a 30% cyanide mixture. (The large furnace holds about 900 lbs. of the straight sodium cyanide and 1300 lbs. of the 30% mixture.) The plates are suspended from racks and held in the bath at varying temperatures and time (between 1500 and 1650 deg. F., and 6-15 min.) according to the sizes and type of steel. They are then quenched in oil without subsequent tempering. The scleroscope hardness desired varies from 38 to 40. Later, the plates are bent to a curved shape for transfer of the impression and it is imperative that the core be soft enough to withstand this bend, and also that the case be so graded as not to crack or distort in this operation.

The pot is made of boiler plate; no estimation of its life is possible as there has been no failure in the 10,000 hrs. since the furnace and pot were installed. (This statement applies to all the Ajax-Hultgren furnaces in this shop.) The hardening of these plates, however, is not a continuous operation, so that this furnace, although kept hot, is often not "in use." There is, furthermore, never any necessity for charging more than one plate at a time, and drag-out from this furnace is therefore relatively low. The cyanide content should be at least 25 per cent. Overnight (and over the weekend) the furnace is cut down to 1200 deg. F. but is never shut off. The company's early experience with the bath in this furnace showed that its relative inactivity (believed to be due to low drag-out) could be corrected by the addition of cyanate.

In the first of the small furnaces used for heat treating, 0.45-0.60 per cent C steel dies are immersed for 30 min. in 45 per cent cyanide mixture at 1450 deg. F. The dies are quenched in brine, the surface of which is covered with a layer of oil, and then oven-tempered at 460 deg. F. The as-quenched hardness is 90 scleroscope, the as-tempered 75-80.

The other small furnace is used for heating machined and annealed 0.90 per cent C tool steel rolls to 1550 deg. F. prior to quenching in brine. Here again, a 45 per cent cyanide mixture is employed; the rolls are immersed for periods of 30 min. to 1 hr. (depending on their size) then quenched, and finally tempered at 460 deg. F. In each case the purpose is to harden the roll so that the engraved impression it bears can be transmitted clearly and a large number of times to the annealed steel plates previously described.

Economic comparisons are difficult here, because the company's large furnace is much larger than the old gas-fired pots and therefore uses more salt and more heating energy. The staff of this company's clean, modern hardening department is, however, highly enthusiastic about the furnaces. The heating is much more uniform over the whole bath, and temperatures are reproducible at will. Other advantages cited were the short heating-up time in the morning, and the apparently long pot life obtained; pots were formerly a large and expensive item with this company. The furnace also is comfortable to work with, and evolves no annoying fumes. No trouble with electrodes has been experienced. The metallurgical staff at this time are unable to suggest any further means by which the performance of the furnace could be improved.

## References


[1] E. F. Davis. "New Electric Process for Cyanide and Activated Baths." METALS AND ALLOYS, Vol. 7, June, 1936, pages 143-146.

[2] Wm. Adam, Jr. "The Ajax-Hultgren Salt Bath Furnace." *Trans. Electrochem. Soc.*, Vol. 70, 1936, pages 143-160.

[3] Axel Hultgren. "The Electrode Salt Bath for Hardening High Speed Steel." *Trans. Amer. Soc. Metals,* Vol. 25, Dec. 1937, pages 1166-1177.

[4] R. R. Abbott. "Use of Salt Pot Furnace Improves Heat-Treating of Automotive Parts." *Electrical Production Magazine,* (Elec. League of Cleveland), Sept., 1937.

[5] R. Flury. "Heat Treatment of Steering Gear Parts." *Industrial Heating,* Vol. 5, Feb., 1938, pages 131-138, 160.

[6] A. von Zeerleder. "Der Ajax-Hultgren-Salzbadofen." *Elektrowärme,* Vol. 8, Apr., 1938, pages 105-106.

THE PROPERTIES OF

# High Purity Aluminum

by C. S. Taylor,
L. A. Willey,
Dana W. Smith and
Junius D. Edwards

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*New Kensington, Pa.*

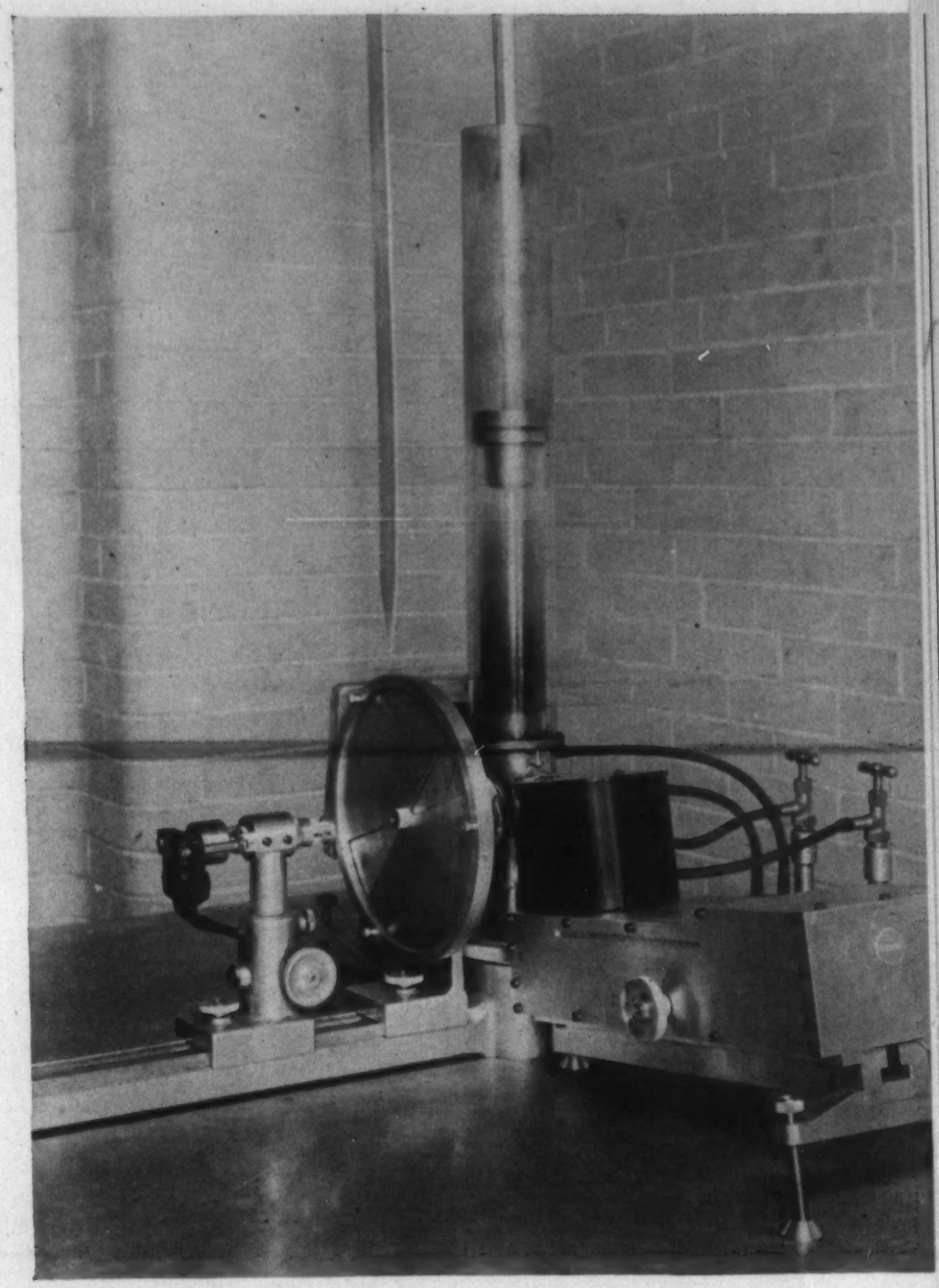

*Fig. 1—X-ray Tube with Cameras for Measuring Lattic Parameter. The film is held in circular holder with sectors cut in metal face plate; X-ray beam passes through hole in axis of film-holder and strikes specimen directly opposite.*

**The research laboratory of the Aluminum Company recently completed a series of measurements of some of the physical properties of very pure aluminum, which not only gives a number of physical constants which have not been available for aluminum of this purity but which also are unique in that they were all made on metal of the same composition. From a two-page summary of these results, data sheets are to be published in the August issue of *Metal Progress*. Because of the scientific and practical importance of its figures, a more complete presentation seemed warranted as contained in this article.—The Editors.**

THE FIRST PUBLIC ANNOUNCEMENT of the production of "pure aluminum" by the Hoopes electrolytic refining process was made in 1925.[4] Simultaneously a paper was published giving data on many of the physical properties of this new high-purity metal.[2]

Of the physical measurements reported at that time, not all were made on metal of the same purity, nor even of the highest purity available, namely, 99.99 per cent. Recently aluminum of even higher purity has been produced by a similar electrolytic process. We have had occasion to make a series of measurements on electrolytically refined aluminum produced by Compagnie des Produits Chimiques et Electrometallurgiques d'Alais Froges et Camargue, which had a purity of 99.996 per cent aluminum.[5] All of these numerous measurements were made on metal of the same carefully analyzed composition and gave us further important information on the properties of metal approximating "pure aluminum."

In preparing the metal for these tests, the high-purity aluminum in the form of notch-bar ingot was remelted in a graphite crucible and cast in the form of a sheet ingot 1½ in. thick. After cold-rolling to a thickness of 1 in., the surface of the slab was removed by machining, and the sheet then further cold-rolled to produce specimens of a size suitable for the various measurements. The metal was then analyzed with the following result:

| | Per Cent |
|---|---|
| Silicon | 0.0020 |
| Iron | 0.0001 |
| Copper | 0.0010 |
| Sodium | 0.0003 |
| Calcium | 0.0003 |
| Magnesium | 0.0003 |
| Aluminum, by difference | 99.9960 |

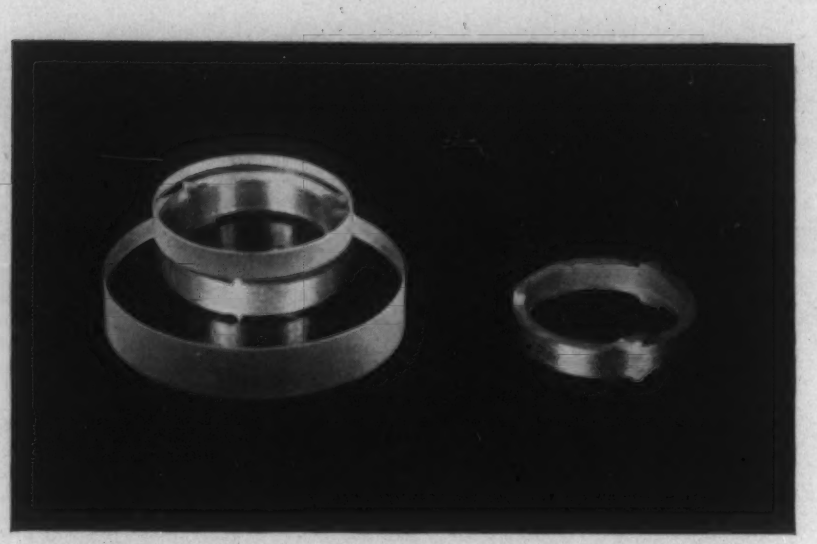

*Fig. 2—Interferometer for Measuring Thermal Expansivity; Two Plane Quartz Plates with Aluminum Sample between; Extra Aluminum Sample at Right to Show Size and Shape. (Full size.)*

There are naturally many difficulties encountered in the exact analysis of metal of such high purity as this, and both chemical and spectrographic methods were employed to insure the accuracy of the results. While electrolytically refined aluminum of purity as high as 99.999 per cent has been reported, it could not be assumed, without further test, that such metal is necessarily purer than the sample under investigation. The analysis just given reports small amounts of sodium, calcium and magnesium, which are not ordinarily determined in the analysis of aluminum. Suffice it to say, however, that it is very pure metal.

## Melting Point

The melting-point was determined with a platinum-rhodium thermocouple. This couple was calibrated by determining the melting-point of Bureau of Standards standard sample of aluminum, No. 44C, which the Bureau certifies to have a melting-point of $660.1_5$ deg. C. The melting-point of high-purity aluminum (99.996) was found to be $660.2_4$ deg. C.

## Thermal Expansivity

Thermal expansivity has been measured by an interferometric method capable of measuring changes in length of 0.00001 mm. The test specimens for the thermal expansivity measurements comprised rings about 0.7 in. in diameter by 0.2 in. in height, made by bending a narrow strip of 14 gage sheet into a circle. By filing away part of the metal, small legs or pins were produced on each edge of the ring, and these legs extended about 0.02 to 0.03 in. from the body of the ring. The legs were angularly displaced from each other by about 120 deg.

Such a specimen was introduced between two quartz optical flats, forming an interferometer. One leg on the specimen was slightly longer than the other two, so that the quartz plates separated by the specimen were not exactly parallel, and the difference in length was carefully adjusted by polishing, so as to produce the desired number of interference fringes. The interferometer was then set in an aluminum block, which itself was set within a furnace. The aluminum block was a thick-walled aluminum container with a cover and a quartz window for holding the interferometer, and by its mass assisted in maintaining a very constant temperature of the specimen under measurement.

The height or length of the specimen, approximately 5 mm., was measured at constant temperature, using a Zeiss interference measuring apparatus. The distance between the interferometer plates, and therefore the length of the specimen at any temperature was measured to an accuracy of $\pm 0.00001$ mm. However, the thermal expansivity of the specimen could not be determined with this precision, because of uncontrollable changes occurring within the specimen, such as recrystallization and grain growth, or changes at the interfaces between specimen and the interferometer plates, such as growth of the oxide film on the aluminum or relative motion of the specimen and plates. The temperature of the specimen was controlled with an accuracy of $\pm 0.1$ deg. C. In order to avoid the effect of permanent changes in the specimen resulting from grain growth, the practice was employed of heating the specimen through the full range of temperatures before undertaking any actual measurement of thermal expansivity.

Measurements were made on three different test specimens, and the average linear coefficients of thermal expansion for these three specimens are given in Table I for a number of ranges of temperatures from 20 deg C. to 500 deg. C. The experimental agreement between the results of test specimens 1 and 3 is quite close. Careful examination of the results, however, discloses no particular

**Table I.—AVERAGE LINEAR COEFFICIENTS OF THERMAL EXPANSION OF ALUMINUM—(99.996)**

| Temperature Range, Deg. C. | Average Coefficient of Expansion per Deg. C. × $10^{-6}$ | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | Aver. |
| 20 to 100 | 23.84 | 23.92 | 23.83 | 23.86 |
| 20 to 200 | 24.53 | 24.67 | 24.54 | 24.58 |
| 20 to 300 | 25.39 | 25.56 | 25.41 | 25.45 |
| 20 to 400 | 26.43 | 26.58 | 26.45 | 26.49 |
| 20 to 500 | 27.64 | 27.74 | 27.65 | 27.68 |

reason for the slightly higher values obtained with test specimen No. 2, so that all three values have been included in the averages. The thermal expansivity of this aluminum between 20 and 500 deg. C. is represented by the following empirical equation:

$$L_t = L_o\,[1 + (23.22t + 0.00467t^2 + 0.0000078t^3)10^{-6}],$$

where $L_o$ is the length at 0 deg. C. and $L_t$ the length at temperature t. The standard deviation calculated from 23 tests equals 0.000023 per unit length. The arithmetical mean of the deviations from the curve equals + 0.000003.

These results are in fair agreement with those obtained at the Bureau of Standards by Hidnert.[6] According to Hidnert, the expansivity of cast aluminum (99.95 per cent) from room temperature to about 610 deg. C. is given by the equation—

$$L_t = L_o\,[1 + (22.58t + 0.00989t^2)10^{-6}].$$

The average coefficients of expansion per deg. C. computed from this equation are $23.8 \times 10^{-6}$, $24.7 \times 10^{-6}$, $25.7 \times 10^{-6}$, $26.7 \times 10^{-6}$, and $27.7 \times 10^{-6}$, for the temperature ranges 20 to 100, 20 to 200, 20 to 300, 20 to 400, and 20 to 500 deg. C., respectively.

## Lattice Parameter

Back reflection X-ray diffraction patterns were made from two specimens on one plate. The test specimens were $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{4}$ in. in size and had been annealed in a salt bath for 4 hrs. at 200 deg. C. A record of the temperature of each sample during exposure was made using a two-couple thermo-pile and a potentiometer. The maximum variation in sample temperature during any given exposure was $\pm$ 0.1 deg. C. This variation would cause negligible variations in lattice parameter since a thermal coefficient of ex-

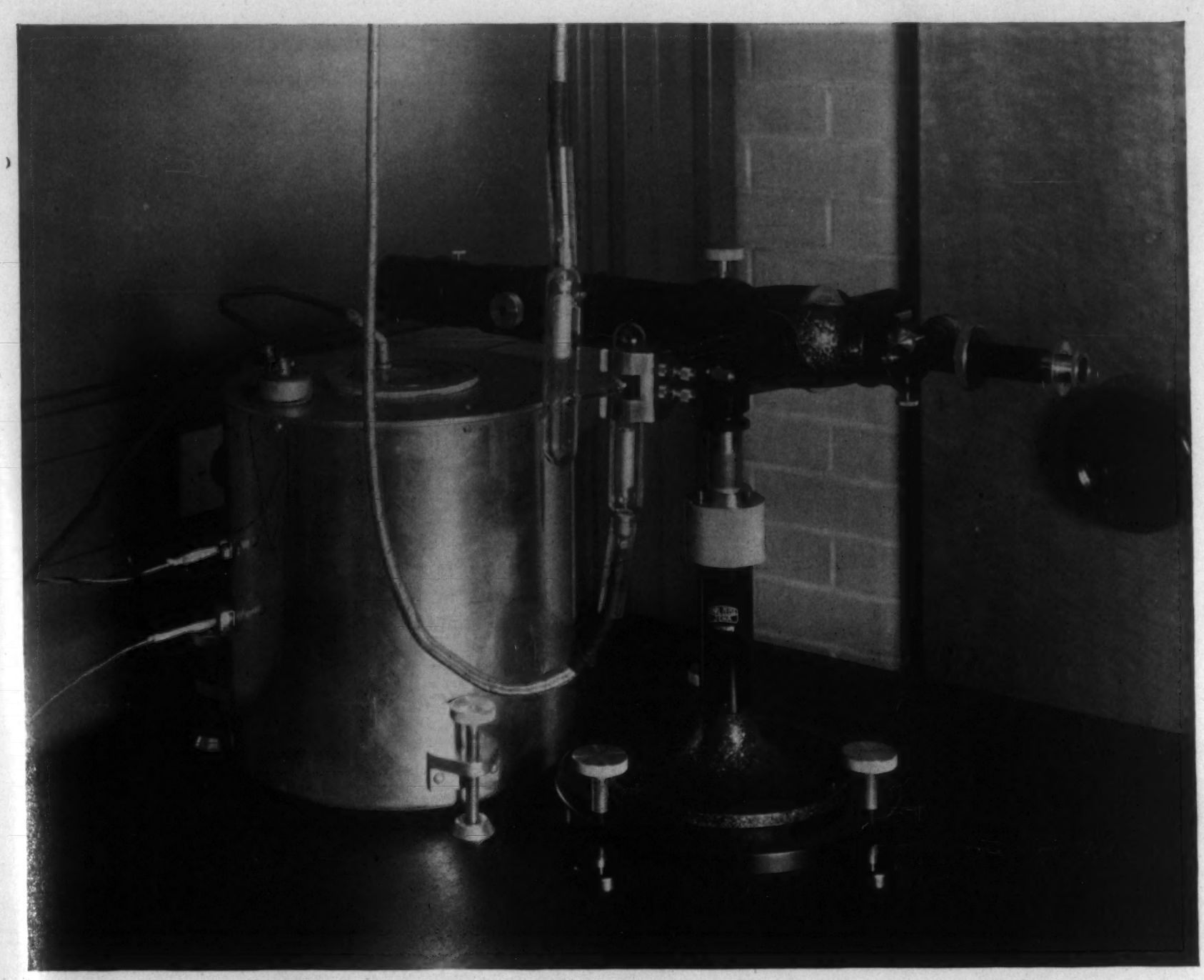

*Fig. 3—Dilatometer. Thermostatically-controlled furnace which holds interferometer at left; interferometer reading device at right.*

pansion of 23 x $10^{-6}$ would yield a change in parameter of slightly less than 0.0001 Å.U. per 1 deg C.

The diameters of the diffraction circles were measured by means of a microphotometer-comparator to an estimated accuracy of ± 0.02 mm. and the distance between specimen and plate to an estimated accuracy of ± 0.01 mm.

The results of the lattice parameter measurements made on two specimens are given in Table II.

**TABLE II.—LATTICE PARAMETER OF ALUMINUM (99.996)**

| Test Number | Specimen-plate distance (x) | Diameter of $Q^2 = 27(Al)$ $CuK\alpha_1$ diff. circle | Temperature, Deg. C. | a (A. U.) |
|---|---|---|---|---|
| 1 | 74.35 | 46.99 | 26.6 ± 0.0 | 4.0415 |
| 2 | 74.35 | 46.99 | 27.6 ± 0.1 | 4.0415 |

The lattice parameter of aluminum (99.996) is:

4.0413 ± 0.0001 Å.U. at 25°C.

This parameter value is in close agreement with that reported by A. Ievins and M. Straumanis,[7] $4.0414_5$ ± $0.0000_2$ Å.U. at 25 deg. C. for aluminum of approximately the same purity.

The density of this same material calculated from our measured value of the lattice parameter is:

2.6953 gm/cc at 20°C.

This value for density is slightly lower than the value measured by the classical (weight) method.

## Density and Electrical Properties

The density of aluminum was determined by the method of hydrostatic weighing. Small samples of 14 gage sheet, annealed by heating for 4 hrs. at 200 deg. C., gave the following results:—

Density at 25 deg. C.—2.6978 grams per cc.
Density at 20 deg. C.—2.6989 grams per cc.

The electrical resistivity of the high-purity aluminum was determined with strips of 14 gage sheet, 1 in. wide, 24 in. long. The strips were held in a constant temperature oil bath regulated to ± 0.02 deg. C. The test specimen was placed in series with a standard resistance of 0.001 ohm, calibrated by the National Bureau of Standards. The resistivity was measured by comparing the potential drop across the standard resistance and across a measured length of the test specimen when a current of about 5 amperes was flowing through both. By means of measurements at two temperatures, the temperature coefficient of resistance was determined. The resistivity temperature coefficient and several related constants are given in the following tabulation:—

**TABLE III.—SOME ELECTRICAL CONSTANTS OF ALUMINUM (99.996)**

| | |
|---|---|
| Volume resistivity in microhm-cm at 20 deg. C. | 2.6548 |
| Volume per cent conductivity (International annealed copper standard = 100%) | 64.94 |
| Mass resistivity in ohms (meter, gram) at 20 deg. C. | 0.07165 |
| Mass per cent conductivity (International annealed copper standard = 100%) | 213.92 |
| 20 deg. C. constant mass temperature coefficient of resistance | 0.00429 |

## Mechanical Properties

Certain mechanical properties were determined on specimens of 14 gage sheet cut across the direction of rolling. The determinations were made on three specimens of the cold-rolled material (75% reduction), and on three specimens of the material which had been annealed by heating for 4 hrs. at 200 deg. C. The results of the tests are given in Table IV.

**TABLE IV.—MECHANICAL PROPERTIES OF ALUMINUM (99.996)**

| Temper | Tensile Strength, lb. per sq. in. | Yield Strength,* lb. per sq. in. | Per Cent Elongation in 2 in. | Brinell Hardness Number** |
|---|---|---|---|---|
| Cold-rolled | 16,410 | 15,500 | 5.5 | |
| Cold-rolled | 16,330 | 15,500 | 5.0 | |
| Cold-rolled | 16,160 | 15,300 | 6.0 | |
| Average | 16,300 | 15,430 | 5.5 | 27 |
| Annealed | 6,900 | 1,800 | 47.0 | |
| Annealed | 6,860 | 1,700 | 48.5 | |
| Annealed | 6,860 | 1,800 | 51.0 | |
| Average | 6,870 | 1,770 | 48.8 | 17 |

* For a permanent set of 0.2 per cent.
** 12.61 Kg. on 1/16-in. ball.

Aluminum of the high purity under consideration is very susceptible to grain growth during annealing. Coarsening of the grain has an important effect on both tensile strength and elongation. The mechanical properties being influenced in an important way by grain structure are no intrinsic function of purity. The samples described in Table IV were annealed for 4 hrs. at 200 deg. C. and had what may be called a medium grain size.

In connection with the subject of annealing, it may be noted that Calvet[1] found that recrystallization began at room temperature with cold-worked aluminum having a purity of 99.998. The specimens of cold-rolled temper shown in Table IV were tested within an hour of rolling in order to avoid any appreciable softening.

## Radiation Characteristics

Reflection and emissivity measurements were made on samples of the high-purity aluminum sheet. In order to develop maximum reflectivity, the samples were first electrolytically brightened by the process of R. B. Mason.[3] The reflectivity, that is, the total reflection for light from a tungsten filament lamp, was measured by the method of A. H. Taylor[8] and found to be 90 per cent. Aluminum films formed by the vaporization of aluminum and condensation in vacuo have shown, by the same method of measurement, reflectivities only a little higher.

The thermal emissivity of the same specimen held at a temperature of 100 deg. F. was determined by means of a sensitive radiometer. Using a value of 5 per cent for the emissivity of bright aluminum foil having a purity of about 99.5 per cent, this high-purity aluminum was found to have an emissivity of 4.5 per cent. A survey of the published data indicates that the emissivity of bright commercial foil may be as low as 3 per cent, in which case the value just given for the very pure aluminum would be 2.6 per cent. Until, however, some established standard of low emissivity is available, we have chosen to use the conservative figure of 5 per cent for the emissivity of the foil used in calibrating the radiometer.

## References


[1] J. Calvet. *Compt. rend.*, Vol. 200, 1935, p. 66.
[2] Junius David Edwards. *Trans. Am. Electrochem. Soc.*, Vol. 47, 1925, p. 287.
[3] Junius David Edwards. *Trans. Illum. Eng. Soc.*, Vol. 29, 1934, p. 351.
[4] Francis C. Frary. *Trans. Am. Electrochem. Soc.*, Vol. 47, 1925, p. 275.
[5] R. Gadeau. *Rev. l'aluminium*, Vol. 12, 1935, p. 2831. *Aluminium*, Vol. 18, 1936, p. 14. *Aluminium and Non-Ferrous Rev.*, Vol. 1, 1936. pp. 499, 535.
[6] Peter Hidnert. *Bur. Standards Sci. Paper* No. 497, 1925.
[7] A. Ievins & M. Straumanis. *Z. physik. Chem.* Vol. B34, 1936, p. 402.
[8] A. H. Taylor. *Bur. Standards Sci. Paper No.* 405, 1920.


## Bibliography


J. Calvet, Jean J. Trillat & Miloslav Paic. *Compt. rend.*, Vol. 201, 1935, p. 426.
W. Feldman. *Aluminium*, Vol. 20, 1938, p. 73.
G. G. Gauthier. *Aluminium*, Vol. 18, 1936, p. 564.
Maurice Henri. *Rev. Mét.*, Vol. 33, 1936, p. 420.
Hans Schiek. *Aluminium*, Vol. 20, 1938, p. 75.


# Editorial *(Continued from page A 13)*

leave the present setup to be remedied, and for this we have a suggestion.

Divide the annual cost of supporting the unemployed by the number of unemployed. The quotient is what it costs now per man per year. Let each taxpayer hire a man Friday for this sum and get that much credit on his taxes. Instead of boondoggling and leaning on shovels, the Fridays can free their personal employer from things he has to do that limit his time for constructive work and thought. In our own case, Friday could cut grass, shovel snow, wash the car, run errands, and even at those times when we haven't any ideas, write editorials.

Robinson Crusoe had no depression after Friday appeared on the scene.—H.W.G.

## Engineering Materials For the Foundry

Quite seriously set forth by Lamoreux in *Revue de Fonderie* for April 10 (and equally seriously abstracted by *Giesserei* for May 6,) is the argument that up to about 1904 it was customary to use horse manure as a foundry core binder and there was no trouble from defective castings due to poor cores. Hence, he argues, all the newfangled binders should be eliminated and the good old standby reinstated.

While there might be some question whether the castings the foundry has to make today are not a bit more complicated than those of 30 years ago, the major difficulty, in the United States, is to find some automobile by-product that will do instead, so that, following the example of the totalitarian states, we may be self-sufficient and not have to import horse manure from the Continent or the land of the Rising Sun.

It might, however, serve to substitute bull, of which we have a large domestic supply, and the crop will be especially luxuriant this fall, since it is an election year. Perhaps the mere installation of a radio in the core room during broadcasts from Washington would be enough.—H.W.G.

# Vanadium in Steel and Iron

## —A REVIEW

**Part I**


## by W. J. Priestley

*Vice President,*
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**Since its introduction as an alloying element for steel and iron over 20 years ago, the importance and applications of vanadium have expanded. Today vanadium is widely used, either by itself or in conjunction with other alloys, so that the number of steels into which vanadium enters is large. Also, the uses to which such alloy steels and irons are put are constantly broadening.**

**This article is a review of the entire field, both as to composition, properties and applications of vanadium alloy steels and irons, by an authority in the metallurgical engineering industry.**

**—The Editors**


IT WAS IN 1801, that Manuel del Rio, professor of mineralogy at the School of Mines in Mexico City, first examined some brown lead ores from the Zimapan district of Mexico. These ores had such an unusual appearance to his trained eye, that he brought some back to the University for further examination. There, after a number of tedious experiments in reduction of the material, he obtained an impure silvery metallic mass somewhat similar to chromium and uranium, yet different from any other metal then known. The material readily reacted chemical-

*Careful Heat Treatment Assures the High Strength, Toughne ss and Good Ductility of the Chromium-Vanadium Steel Mast Fittings, Turnbuckles, Clevises, Pins and Other Parts of the Rigging on the "Ranger," Victor of the America's Cup Race Last Year.*

*The Highly Stressed Chromium-Vanadium Steel Impeller Shaft of this Tie Tamper is Oil Quenched and Tempered to a Hardness of Rockwell C-59. (Courtesy: The Buda Co.)*

ly, and as the salts became red upon heating he named his new substance "erythronium".[1]

Del Rio decided to incorporate his discovery into a paper, but, in anticipation of any questions as to the source of his knowledge, he determined first to study the subject exhaustively. Further experiments led him to doubt that he had discovered a new metal, and uncertainty got the better of him. Thus, his paper lost much of its glamour when published as the "Discovery of Chromium in the Brown Lead Ore of Zimapan." Later, his mistaken analysis was confirmed and "erythronium" was almost forgotten.

Almost thirty years later, a Swedish chemist, Nils Sefström, isolated some beautifully colored compounds from slag produced from melting the Täberg iron. In May, 1830, he prepared a metallic mass from the compounds and named the substance "vanadium", in reference to Vanadis, the name sometimes given to Freya, the Scandinavian goddess of beauty. Later in the same year F. Wöhler showed that del Rio's erythronium was identical with Sefström's vanadium. In the next year, Berzelius made quite an extensive study of vanadium compounds. However, from then on, interest in the metal again waned.

For nearly forty years vanadium and its compounds remained in almost complete obscurity. Vanadium was considered to be extremely rare, and, although traces were found in widely scattered ores of lead, zinc, iron, and copper, the concentration was always too low to warrant extraction on a commercial basis. Also, although it was not then realized, none of the earlier investigators had obtained the metal in the uncombined form.

The development of vanadium remained in this dormant state until 1868. At that time, Sir Henry E. Roscoe began an intensive research on the subject. Tests proved that the "erythronium," or vanadium, obtained by the earlier investigators was chiefly the oxide and nitride. Roscoe soon devised a process for preparing the metal in its pure state and tried, by some means, to determine the metal's position in the periodic table of the elements. By the year 1870, he had supplemented practically all of Berzelius' work and had almost exhausted the study from a chemical standpoint.

In spite of all this early development, vanadium did not begin its climb to prominence until about 1896. At the time when Roscoe had been working with the pure metal, there had been some demand for vanadium compounds in the dyeing industry, especially in the preparation of aniline dyes. The beautiful colors produced by certain of its salts already had opened a field for its use in inks and for coloring glass and pottery. Brown, purple, blue, and green glazes were prepared with it.

Not until 1896 was vanadium intentionally introduced into steel. Sefström, back in 1830, had already noted that the fine Täberg iron contained vanadium in extremely small amounts, but until over sixty years later, little thought was

given to the effect a small percentage of vanadium would have on steel. However, in 1896, the Firminy Steel Works in France experimented with several compositions of armor plate steel to which vanadium had been added. The marked improvement in physical properties immediately forecast a great future for such steel.[2]

The discovery of the benefit conferred upon steel by the addition of vanadium prompted a great deal of research by independent investigators into both the production of ferrovanadium and the determination of the effect of varying proportions of vanadium in steel. At the same time, one of the larger sources of vanadium ore, patronite, was discovered in Peru. Carnotite, a potassium uranyl vanadate, was found in Colorado and Utah. Vanadinite was also found appearing as deep red crystals in Arizona, New Mexico, Southeast Africa and Northern Rhodesia. Some of the other vanadium minerals which have come into importance since then are descloizite, a lead zinc vanadate found in New Mexico and Arizona; vanoxite, a hydrated vanadium oxide; and roscoelite, named after Sir Henry Roscoe, which is an important low grade ore found in Colorado. Numerous other smaller sources have also been found, but the principal supply is now obtained from Colorado, Peru, Southeast Africa, and Northern Rhodesia.

*This Complete Tool Kit Contains Many Wrenches and Other Tools of Tough Wear-Resistant Chromium-Vanadium Steel. (Courtesy: Bonney Forge & Tool Works.)*

## Uses of Vanadium

Practically pure vanadium was first obtained by Marden and Rich[3] in 1927 by the reduction of vanadium pentoxide with metallic calcium in the presence of calcium chloride. They give the following data for the physical properties of pure vanadium:

| | |
|---|---|
| Ductility | High (equal to that of tantalum) |
| Melting point, deg. C. | 1,700 |
| Density at 20 deg. C., g. per cu. cm. | 6 |
| Specific Electrical Resistance, ohm per cm. cube | $26 \times 10^{-6}$ |

Up to the present time no important commercial use for pure vanadium has been developed. Nor has non-ferrous metallurgy found many applications for vanadium alloys. A strong, corrosion-resistant alloy of copper containing a small percentage of vanadium has been employed to a limited extent for aircraft propeller bushings and for propellers in salt water service.[5] Also, vanadium has been added to aluminum in order to impart greater strength and increased resistance to corrosion. Aluminum containing up to 10 per cent vanadium is malleable. These applications have been principally experimental, and the amount of vanadium used for such purposes, though now by no means imposing, will undoubtedly grow as further experimentation carries non-ferrous vanadium alloys into the industrial field.

The principal outlet for vanadium at present is in the form of ferrovanadium which contains 35 to 40 per cent vanadium. In Europe a composition containing 45 to 55 per cent of vanadium is common, and in special cases, an 80 per cent alloy is produced. In the form of ferrovanadium, vanadium is being added to cast iron and to steel for castings, forgings, and rolled products.

## Effects of Vanadium in Steel

Vanadium is an excellent deoxidizer and degasifier of molten steel, removing both oxygen and nitrogen. Vanadium degasifies the steel completely, producing a slag which readily makes its way up through the molten steel and leaves very clean, sound metal. In this respect vanadium ranks with aluminum as one of the best known degasifying agents for wild steel.[6]

However, gaseous impurities can be removed by other less expensive alloys and compounds, and since the greatest influence of vanadium is as an alloy in the finished metal, it is usually added to killed steel, in the ladle, after all other quieting additions have been made. It may also be added to electric furnace steel after all other additions have been made, just before pouring from the furnace.

Vanadium progressively increases the tensile strength and, more especially, the elastic limit of steel, until a vanadium content of 1 per cent is reached. Above 1 per cent vanadium, these properties are not increased and may even be decreased. For this reason, structural vanadium steels seldom contain more than 0.15 to 0.25 per cent vanadium. Most steels containing more than 0.50 per cent vanadium are for special purposes. In high-speed steels, the amount of vanadium ranges from 0.50 to 2.50 per cent. In the original 18-4-1 and 18-4-2 types, as well as in the newer cobalt and molybdenum high-speed steels, vanadium is an important factor for increasing cutting ability. The great stability of its carbide, combined with its ability to refine the grain size, probably contributes the major portion of its beneficial effect.

Metallurgically, vanadium has three principal effects upon steel. First, it forms extremely stable, finely dispersed carbides which show very little tendency to decompose or to segregate in large masses on heating. Cementite in vanadium steel occurs in fine particles uniformly distributed throughout the ferrite matrix, and the resultant tendency is for the pearlitic constituent to become sorbitic rather than lamellar. This structure lends itself readily to a spheroidizing annealing treatment with a consequent ease of machining.

Secondly, although vanadium combines principally with

*Forged Chromium-Vanadium Steel Spring Equalizers, Crankpins and Axles, Cast Vanadium Steel Valve Gear Frames and Reverse Yokes, and Forged Manganese-Vanadium Steel Valve Gear Bell Cranks and Radius Bars Help Reduce the Weight of Important Parts of this New High-Speed Passenger Locomotive for the "Twentieth Century." (Courtesy: the New York Central System.)*

cementite, any excess vanadium goes into solid solution in the ferrite and increases the steel's strength, hardness, resistance to abrasion, and resistance to fatigue. Vanadium also adds ductility to the metal.

Finally, because of their finer, more uniform grain size, and minimum tendency toward grain growth in the heat treatment range, vanadium steels have pronounced thermal stability. They are easily heat-treated and rarely require special care during forging.

## Vanadium Constructional Steels

A vanadium steel largely used in construction is essentially material of the following average analysis:[7]

| | |
|---|---|
| Carbon, per cent | 0.50 |
| Manganese, per cent | 0.85 |
| Phosphorus, per cent | 0.04 max. |
| Sulphur, per cent | 0.04 max. |
| Vanadium, per cent | 0.18 |

A considerable tonnage of such carbon-vanadium steel has been used by the railroad industry. For large forgings the heat treatment usually consists of normalizing at 900 deg. C., cooling in still air, reheating to 600 deg. C., and cooling in still air or in a furnace. Typical physical properties obtained with this steel are:

| | |
|---|---|
| Tensile strength, lb. per sq. in. | 95,000 |
| Yield point, lb. per sq. in. | 65,000 |
| Elongation in 2 in., per cent | 23 |
| Reduction of area, per cent | 47 |

Small forgings, heat-treated in the same manner, give even better properties:

| | |
|---|---|
| Tensile strength, lb. per sq. in. | 105,000 |
| Yield point, lb. per sq. in. | 75,000 |
| Elongation in 2 in., per cent | 28 |
| Reduction of area, per cent | 60 |

The use of small forgings of 0.50 per cent carbon, 0.18 per cent vanadium steel is constantly increasing. Typical of its recent uses are automotive engine crankshafts. In this application, their freedom from warping is especially advantageous.

Low-carbon carbon-vanadium steel makes excellent welding rod for oxy-acetylene welding. Here again, the dense, fine-grain structure and great uniformity imparted by vanadium results in welds possessing high strength and considerable resistance to impact.

## Chromium-Vanadium Steels

Chromium-vanadium steels, now one of the largest outlets for vanadium, are used for a variety of purposes. An extremely wide range of properties is obtainable with these steels by suitable treatment. Where toughness, hardness, and resistance to wear are desirable, chromium-vanadium steel may be applied with great success, and these properties can be obtained with but a simple heat treatment.

The presence of both chromium and vanadium in steel raises the temperature at which the carbides pass into solution, and lowers the temperature at which they are precipitated. Since these changes take place slowly, chromium-vanadium steels must be held "at heat" somewhat longer than plain carbon or certain other alloy steels. This slow rate of change prevents harmful grain growth. As a matter of fact, these steels attain their best qualities when held for quite an appreciable length of time at the normalizing temperature. Holding them "at heat" insures that adequate time is allowed for the transformation to be completed, and tends to reduce the danger of careless treatment, providing an unusual factor of safety.

Chromium-vanadium steel can be heat-treated much more simply than some other alloy steels; a single quench followed by a draw is usually sufficient to accomplish the necessary results and produce an excellent refinement of grain. Since they respond in a very uniform manner to heat-treatment, similar results from different heats are readily obtainable.

In general, low-carbon chromium-vanadium steels are employed quite frequently for case-carburized parts, such as wrenches, pistons, pneumatic tool parts, gears, wrist pins, camshafts and other parts subjected to wear involving high stresses. Medium-carbon chromium-vanadium steels are employed for gears, axles, steering arms and, in some cases, for crankshafts, connecting rods, and valve operating parts. Their use for springs will be described below. High-carbon chromium-vanadium steels are used for ball and roller bearings, wearing plates, dies, wrenches and other tools.

In the automotive field, chromium-vanadium steels are used for a large number of highly stressed parts. These chromium-vanadium steels usually contain from 0.80 to 1.10 per cent chromium and between 0.15 and 0.25 per cent vanadium, and are made with a carbon content in standard ranges of from 0.10 to 1.05 per cent. In the range of carbon from 0.35 to 0.45 per cent, the S.A.E. 6140 steels are employed in oil-hardened shafts, driving parts, gears, pinions, and other parts for heavy-duty work.

In addition, their resistance to deterioration when exposed to hydrogen at high temperatures and pressures has made them of particular value for the construction of high-pressure equipment in the chemical industry.

Transmission gears for one type of car are composed of 0.50 per cent carbon chromium-vanadium steel. Rear axle gears and pinions usually contain 0.15 per cent carbon, and chromium-vanadium differential gears contain 0.35 per cent carbon. Steering knuckle pins for another car are of 0.20 per cent carbon chromium-vanadium steel. Striking lever shafts, in the transmissions of certain cars, are of chromium-vanadium steel oil-hardened from 850 deg. C., and tempered at about 600 deg. C. In the soft condition this steel has a Brinell hardness of about 241. Hardened and tempered, the Brinell hardness goes up to 477. In this form chromium-vanadium steel is used in place of case-hardened steel, since the depth of hardness is far greater than could be obtained with a case.

In the mining industry, steels containing chromium and vanadium find a variety of uses. With the usual chromium content of 0.80 to 1.10 per cent, and a vanadium content of 0.18 per cent, chromium-vanadium steel is used for shafts for steam shovels and other heavy-duty equipment. Highly stressed bolts, studs, and pins; cylinders and barrels for pneumatic hammers; and clutch gearing made of this steel are very satisfactory.

## Manganese-Vanadium Steels

Several classes of steels are now being made more uniformly and with better properties due to the addition of vanadium. Medium-manganese steels, a class which has long proved erratic in properties from heat to heat, are more uniform if they contain approximately 0.10 per cent vanadium. Intermediate manganese steels often showed a decided tendency toward segregation, resulting in a martensitic formation in the manganese-rich areas on air cooling. All of the useful properties of vanadium in steel are called into play in overcoming this segregation. Microstructure and physical properties are both improved. Grain growth is retarded, and a more uniform structure guarantees uniformity of results.

Manganese-vanadium steel has assumed a position of considerable importance in the railroad industry. It is used for tanks, cars, and other structures. In addition, because of its high tensile strength, it is often used in shipbuilding. This steel has high strength and ductility in the as-rolled condition—a very important characteristic, since heat treatment after fabrication is often impossible. Moreover, because of its inherently fine grain and its low carbon content, which is made possible by the combination of alloying elements employed, this steel is particularly good for welding. Welds of this steel retain strength and ductility almost equal to that of the original plate, and they show very little tendency toward air-hardening.

A typical analysis of manganese-vanadium steel plate and rolled shapes, which is suitable for all applications of a low alloy, high-strength steel, is as follows:[8]

| | |
|---|---|
| Carbon, per cent | 0.13 to 0.18 |
| Manganese, per cent | 1.20 to 1.45 |
| Silicon, per cent | 0.15 to 0.30 |
| Phosphorus, per cent | 0.04 max. |
| Sulphur, per cent | 0.05 max. |
| Vanadium, per cent | 0.08 to 0.12 |

The average physical properties of this steel are:

| | |
|---|---|
| Tensile strength, lb. per sq. in. | 85,000 to 95,000 |
| Yield point, lb. per sq. in. | 55,000 to 72,000 |
| Elongation in 2 in., per cent | 18 to 27 |
| Reduction of area, per cent | 50 to 70 |

This material also has a high fatigue limit and impact strength.

Another manganese-vanadium steel of slightly higher carbon and manganese content is used in considerable quantities for forgings of small or large cross sections. This steel, which has a particularly fine combination of high yield point and ductility coupled with good resistance to impact, conforms to the following analysis:

| | |
|---|---|
| Carbon, per cent | 0.22 to 0.30 |
| Manganese, per cent | 1.45 to 1.75 |
| Silicon, per cent | 0.15 to 0.30 |
| Phosphorus, per cent | 0.045 max. |
| Sulphur, per cent | 0.050 max. |
| Vanadium, per cent | 0.15 min. |

This analysis is used for manganese-vanadium steel to be used in either large or small sections. The physical properties of normalized and tempered forgings of considerable dimensions are approximately:

| | |
|---|---|
| Tensile strength, lb. per sq. in. | 94,000 |
| Yield point, lb. per sq. in. | 68,000 |
| Elongation in 2 in., per cent | 27 |
| Reduction of area, per cent | 59 |

Even in large masses, the penetration of hardness of this steel is excellent, resulting in uniform hardness throughout the forging. This uniformity of hardness in large sections is also obtained in the quenched and tempered conditions. In one case, figures on a solid axle, 12½ in. in diameter, show a maximum variation in Brinell hardness of only 11 per cent.[9]

Impact strength in the manganese-vanadium structural and forging steels is also high, even in large sections, and it is retained even at very low temperatures. Thus, this composition is suitable for use outdoors in very cold climates and low temperature processes of the chemical industry.

*(To be concluded)*

## A Bit of Poetry from a Foundryman

The following bit of verse has been sent in by Harvey G. Schwarz, of the Pacific Alloy Co., Seattle, Wash. It has been evidently inspired by an advertisement, frequently blazoned in the press, and is offered as an answer to the question:

WHERE DO YOU SPEND YOUR WINTERS?
(adv.)

I spend my winters in a lab.,
A prospect that seems pretty drab
To people who would rather cruise
The South Seas—or just plain booze
at Tampa or Miami Beach,
While I vainly try to reach
Tensiles that would make you screech.

I spend my winters, sir, beside
A furnace till I'm nearly fried.
And while I may not get as tanned
As those upon the Cuban sand,
I'm not as close to getting canned
As if I took your offer kind
And left my foundry life behind.—H. G. S.

# CYCLE ANNEALING

## IN A TWO-DECK FURNACE

**by J. B. Nealey**

*American Gas Assn.,*
*New York.*

PLACING ONE MECHANICAL FURNACE on top of another to save time, space and labor is still a novelty but the most interesting thing about the two furnaces in the foundry of the Ford Motor Co. of Canada, Ltd., at Windsor, Ontario, is that each has been designed to perform the triple operation consisting of high heat, air cool, and reheat, known as cycle annealing. This necessitated delicate temperature and mechanical controls. Such a program of control is readily applicable with fuel gas.

These two pusher type cycle annealing furnaces are continuous in operation and automatic as to temperature control. By placing one above the other, and operating them

*A Side-View of the Double Deck Heat Treating Furnace.*

in opposite directions, one man will load one furnace and unload the other at one end of the installation while a second man performs both services at the other end. These two men constitute the entire crew.

In this case, an air cooling chamber is built integral with the furnace and between the high heat and reheat chambers. This air cool saves a lot of handling mechanism and fuel consumption, the latter through heat conservation.

The lower furnace is used for crankshaft annealing and treats 32 cranks an hour. This furnace is about 61 ft. in length and is divided into chambers as follows:—(1) high heat, (2) central cooling, (3) low heat, and (4) discharge and cooling chamber. The high heat section is again divided into a preheat chamber and a holding and heating chamber. This section, as well as the low heat chamber, at the other end of the furnace, are equipped with gas burners which both over and underfire the work.

The heat cycle for the crankshaft furnace is as follows:

Up to 1650 deg. F. in 2 hrs.
Hold at 1650 deg. F. for 1½ hrs.
Cool to 1200 deg. F. in 30 min.
Hold at 1200 deg. F. for 1 hr.
Heat to 1400 deg. F. in 45 min.
Hold at 1400 deg. F. for 2 hrs.
Allow to cool to oven temperature

[The composition of the crankshafts as given in an article, "The Story of the Ford Cast Crankshaft," METALS AND ALLOYS, Vol. 6, Oct., 1935, page 259, is as follows: C 1.35 to 1.60; Mn 0.60 to 0.80; Si 0.85 to 1.10; Cu 1.50 to 2.00; Cr 0.40 to 0.50; P 0.10 max. and S 0.06 per cent max.]

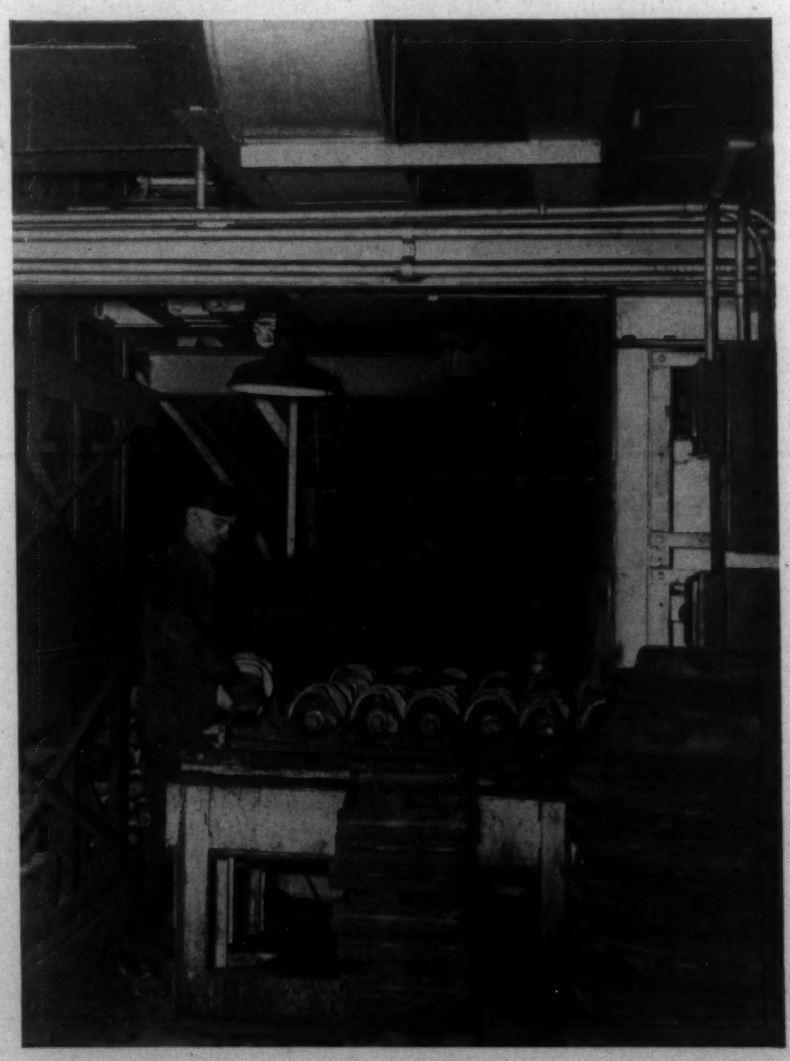
Regardless of fluctuations in the volume of work, and the demand upon the furnaces, the heat input is automatically regulated to meet these demands, and the various temperatures and gas-air ratios are maintained constant by mechanical control. Gas of 1045 B.t.u. is furnished to the burners at 25 lbs. pressure and venturi are used to inspirate the air for combustion. The gas burners located in the different zones or chambers are manifolded in groups, each group including the burners on both sides of the furnace. Each manifold is provided with a valve operated by an automatic temperature control which in turn is actuated by a thermocouple placed in the corresponding zone or chamber. In this way the exact temperature cycle from zone to zone is maintained. Recording pyrometers are included. The gas burners in both of the heating sections of the lower furnace are manifolded into two groups for two-zone control.

The central cooling chamber has cooling flues built in the floor and side walls as well as in the inspection doors and these flues are connected by dampered pipes to a blower. The arch in this chamber is perforated to permit quick cooling and the openings are covered with alloy plates. Two lines of work pass through the furnace on two tracks, each track consisting of two U-shaped rails fitted with rollers. In order to take care of expansion and contraction the rails are cast in short sections in pairs and these sections are held in place by cross bars secured to the furnace walls. The cranks are pushed through the furnace on carrier blocks riding on the rollers. The cranks are lifted off manually at the discharge end and the carriers are returned by a conveyor suspended from the platform or 2 ft. walkway which runs around the upper furnace and is supported by the backstage of the lower.

The system by which the work is moved through the furnace consists of a pusher operated by a 500-lb. hydraulic

*Rear End of Furnace with Gate Closed*

*Crankshafts Emerging from One End of One of the Double Decked Furnaces.*



system with fully automatic mechanical and electrical controls which are in turn operated by a time clock.

The upper furnace is for brake drums and brake hubs, and is also a pusher type roller rail unit, so designed that it can also be used for other castings. It was built to the same general specifications, except that it is larger and is equipped with elevators for loading and unloading and an automatic pull out device. This unit is also continuous in operation and automatic as to temperature control. The conveyor and pusher systems are controlled by hydraulic and electrical equipment which makes it fully automatic and the operation of the furnace requires the services of but one man.

This furnace also has the triple cycle of high heat, air cool and low heat. It also employs fuel gas. The time and temperature cycle, while very similar to that for the lower furnace, differs somewhat. It is as follows:

Heat up to 1750 deg. F. in 2 hrs.
Hold at 1750 deg. F. for 2 hrs.
Cool to 1300 deg. F. in 2 hrs.
Hold at 1300 deg. F. for 1½ hrs.
Cool at 1200 deg. F. in 30 min.
Hold at 1200 deg. F. for 2 hrs.

This is a total time of 10 hrs. based on a loading of 9 drums per tray, the trays being 14 in. long and 29 in. wide, skeleton construction. [The composition of the brake drums, as given in the article "The Metallurgical Story of the Ford Brake Drums," METALS AND ALLOYS, Vol. 8, Nov. 1937, p. 303, is as follows: C 1.55 to 1.70; Mn 0.70 to 0.90; Si 0.90 to 1.10; Cu 2.00 to 2.25, P 0.10 max. and S 0.08 per cent max.]

The gas burners in the heating chamber both over and underfire the work and are manifolded in two groups. Automatic temperature controls provide a two-zone temperature cycle. The temperature of the holding chamber is controlled in one zone only. The discharge and cooling chamber is underfired and controlled in two zones. The first cooling or air quench chamber has ducts and blower equipment similar to that in the lower furnace.

This furnace is 85 ft. in length which allows plenty of hangover, at both ends for operation of the elevators which raise and lower the work at the charging and discharging ends respectively. The rails and rollers of the two tracks are the same as described and are centered over those of the lower furnace to make the entire unit more flexible.

Both furnaces are 6 ft. wide inside and 9½ ft. wide outside and are well insulated. The floors are of 2½ in. of firebrick laid on 7½ in. of insulating brick. The walls, up to the hearth level, consist of 4½ in. of firebrick backed up by 10 in. of insulating brick. Above the hearth level, including the arch, 9 in. of insulating firebrick is backed by 5 in. of insulating brick. The floors of the cooling chambers are of 2½ in. of firebrick and 5 in. of insulating brick while the walls and roof are composed of 4½ in. of firebrick and 5 in. of insulating brick. The supporting piers, forming the division walls consist of 9 in. of firebrick. The combustion chambers below the rails are covered with silicon carbide tile 1¼ in. thick.

The pusher, door, "puller out" and elevator mechanisms of the upper furnace are all operated hydraulically by rams (on 500 lb. oil), hydraulic valves, electrical controls and a time clock. The whole system on the upper furnace is interlocked electrically and mechanically to make a fully automatic unit operating as follows: (1) clock makes contact and discharge elevator rises, (2) discharge door is raised and "puller out" advances and pulls out two trays and remains out, (3) discharge door lowers, (4) discharge elevator lowers, (5) charge elevator raises lifting charging door, (6) rams push two trays into the furnace and at the same time push both rows of work along one tray width, (7) pusher withdraws and (8) charge elevator lowers, dropping the door and thereby completing the cycle. In the above cycle the two trays mentioned, are, of course, two wide, one on each track.

With these and other gas-fired mechanical furnaces, many of the problems of the metallurgist have been solved. Such furnaces are in reality heating machines for mass production and can be placed in the production line and their speeds synchronized with those of the other tools that go to make up the line. They can be counted on for the same dependable flexibility and economy.

EXTRACTION OF OXIDE

# Inclusions in High Carbon Iron

## —ELECTROLYTIC IODINE METHOD

**Part II**

Concluded from July Issue

by Frank W. Scott

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## EFFECT OF ANALYSIS OF IRON ALLOYS ON OXIDE EXTRACTION

DURING the year 1935-1936 an extensive study of oxides in basic pig iron was made using the electrolytic iodine method for their extraction. The results, reported by T. L. Joseph,[39] showed that while the average oxide content was low, occasional pig iron casts would contain appreciable amounts of silicates. Mr. Joseph reported the results of 475 casts of basic pig iron, noted that the oxide content was variable, but could find no relationship between this variation and other variables such as furnace practice and temperature, or iron analysis.

To check the chemical analysis, the iron was examined microscopically with magnification varying from 50 to 1000 diameters. The accompanying photomicrographs show both the extraordinary type of inclusions occurring in the iron high in oxides, and the more usual and typical types occurring in the iron low in oxides.

Fig. 1 shows an extraordinarily large ferrous silicate inclusion. A few such inclusions would give the high results occasionally found. Fig. 2 shows some large silicates, high in silica. It is interesting to note the association with the graphite. Fig. 3 shows a much higher magnification of an inclusion similar to that of Fig. 1. This glassy inclusion has been melted, but has solidified, entrapping small pellets of metallic iron. The chemical analysis of the inclusion will necessarily indicate a higher ferrous oxide analysis than will be true, due to this entrapment. Figs. 4 and 5 show the typical inclusion found. It is very small and crystalline, and few are observed in a single field. Such inclusions were characteristic in all the iron, and were too small for identification.

While microscopic study does not offer a quantitative method for oxide analysis, it does show that inclusions are present, and that they may occur in large segregates.

This work was carried out on basic pig iron, which had small variations in analysis. Foundry iron and gray iron castings cover a wider range of composition, particularly with respect to phosphorus, silicon, and sulfur. In order to study the effect of large variations in analysis on the method for oxide extraction, it was believed desirable to exceed the normal concentration of the various metalloids. Accordingly, the present study was made to determine whether wide variations in composition of the iron affect the amount or the composition of the oxides present.

*Fig. 1. Large Ferrous Silicate Inclusion. Unetched. 50 X.*

## Preparation of the Samples

First, a high carbon iron was produced, by melting Armco iron in a carbon crucible, in an electric furnace. This iron was used as the base for the production of the other alloys. It contained a trace of silicate and aluminate inclusions, carried through from the ingot iron. Also, it contained small amounts of manganese and phosphorus, while the sulphur was variable as the carbon crucibles apparently added a bit of this element to the melt as well as the carbon.

The low metalloid iron was in the form of squares, about 1½ in. on the sides, and had been cut from a ¼-in. plate in the "as rolled" condition. The surface was oxidized, and the iron itself contained appreciable amounts of iron and manganese oxides, with the traces of silica and alumina. A kilogram of these squares was melted in the crucible, being mixed with powdered carbon, and the melt was stirred with a small carbon electrode until the effervescence stopped, and then it was held at a temperature ranging from 1500 to 1550 deg. C. by the optical pyrometer, for 20 min., with the crucible being tightly covered. This allowed the slag particles to rise from the bath, and then they were skimmed off and a chill test poured. The chill test mold was a split graphite electrode hollowed out to produce a thin plate ⅛ in. thick, 2 in. wide, and 4 in. long. The remainder of the metal, in the covered carbon crucible, was cooled slowly, allowing approximately 18 hrs. for the metal to reach room temperature.

The manganese, silicon, phosphorus, sulphur, and the different combinations of these alloys, were made by adding the appropriate ferroalloy in the desired amount after the slag had been removed. The melt was held 10 min. before pouring the test sample after the alloy was melted and stirred in with the carbon rod. In the case of silicon, the desired analysis was difficult to obtain because of the loss by oxidation at the surface of the melt.

The preparation of the chilled samples for extraction required considerable care as they were very hard and brittle. The surface had to be cleaned by surface grinding. When all the scale had been removed, samples 1 in. wide and 4 in. long were cut using an abrasive "cutting off" wheel. Some samples were so strained that they broke into several pieces during this operation, and several

### Table of Chemical and Oxide Analysis

#### 1. Low Metalloid Iron

Chemical Analysis, Per Cent:

| Sample | C | Mn | P | S | Si |
|---|---|---|---|---|---|
| 1 ..... | 0.022 | 0.028 | 0.007 | 0.030 | 0.006 |
| 2 ..... | 0.034 | 0.025 | 0.009 | 0.050 | 0.005 |
| 3 ..... | 0.040 | 0.030 | 0.008 | 0.034 | 0.006 |
| 4 ..... | 0.036 | 0.025 | 0.010 | 0.042 | 0.004 |
| Aver. .... | 0.033 | 0.027 | 0.009 | 0.040 | 0.005 |

Oxide Analysis, Per Cent:

| | $SiO_2$ | MnO | FeO | $Al_2O_3$ | Calcul'd $O_2$ |
|---|---|---|---|---|---|
| I ..... | 0.0015 | 0.0136 | 0.1485 | 0.0042 | 0.0389 |
| II ..... | 0.0012 | 0.0104 | 0.1946 | 0.0030 | 0.0477 |
| III ..... | 0.0013 | 0.0097 | 0.1131 | 0.0046 | 0.0302 |
| IV ..... | 0.0012 | 0.0141 | 0.2049 | 0.0037 | 0.0511 |
| Aver. .... | 0.0013 | 0.0120 | 0.1653 | 0.0039 | 0.0420 |

#### 2. Iron—Carbon Alloy

Chemical Analysis, Per Cent:

| Sample | Total C | G.C. | C.C. | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| 1 ..... | 6.03 | 4.33 | 1.70 | 0.025 | 0.007 | 0.044 | 0.007 |
| 2 ..... | 4.60 | 3.98 | 0.62 | 0.030 | 0.012 | 0.081 | 0.005 |

Oxide Analysis, Per Cent:

| | $SiO_2$ | MnO | FeO | $Al_2O_3$ | Calcul'd $O_2$ |
|---|---|---|---|---|---|
| 1. Slow cooled | 0.0035 | nil | 0.0048 | 0.0053 | 0.0054 |
| 1. Chilled ... | 0.0020 | nil | 0.0048 | 0.0054 | 0.0046 |
| 2. Slow cooled | 0.0034 | nil | 0.0167 | 0.0065 | 0.0087 |
| 2. Chilled ... | 0.0028 | nil | 0.0045 | 0.0052 | 0.0050 |
| Average ..... | 0.0029 | nil | 0.0077 | 0.0056 | 0.0058 |

#### 3. Iron-Carbon-Manganese Alloy.

Chemical Analysis, Per Cent:

| Sample | Total C | G.C. | C.C. | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| 1 ..... | 6.03 | 5.18 | 0.85 | 0.71 | 0.008 | 0.037 | 0.024 |
| 2 ..... | 5.60 | 4.84 | 0.76 | 1.12 | 0.010 | 0.033 | 0.024 |
| 3 ..... | 5.42 | 4.72 | 0.70 | 2.07 | 0.011 | 0.034 | 0.033 |
| 4 ..... | 5.36 | 0.65 | 4.71 | 3.68 | 0.010 | 0.030 | 0.023 |

Oxide Analysis, Per Cent:

| Sample | $SiO_2$ | MnO | FeO | $Al_2O_3$ | Calcul'd $O_2$ |
|---|---|---|---|---|---|
| 1. Slow cooled | 0.0019 | 0.0002 | 0.0031 | 0.0063 | 0.0047 |
| 1. Chilled ... | 0.0026 | nil | 0.0012 | 0.0051 | 0.0040 |
| 2. Slow cooled | 0.0007 | 0.0009 | 0.0028 | 0.0057 | 0.0039 |
| 2. Chilled ... | 0.0030 | nil | 0.0012 | 0.0075 | 0.0044 |
| 3. Slow cooled | 0.0025 | 0.0003 | 0.0037 | 0.0043 | 0.0042 |
| 3. Chilled ... | 0.0034 | 0.0002 | 0.0081 | 0.0037 | 0.0054 |
| 4. Slow cooled | 0.0029 | nil | 0.0086 | 0.0087 | 0.0065 |
| 4. Chilled ... | 0.0023 | nil | 0.0025 | 0.0055 | 0.0045 |
| Aver. ..... | 0.0024 | 0.0002 | 0.0039 | 0.0058 | 0.0047 |

#### 4. Iron-Carbon-Phosphorus Alloy.

Chemical Analysis, Per Cent:

| Sample | Total C | G.C. | C.C. | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| 1 ..... | 5.16 | 3.82 | 1.34 | 0.025 | 0.133 | 0.074 | 0.023 |
| 2 ..... | 5.24 | 1.92 | 3.32 | 0.040 | 0.213 | 0.073 | 0.035 |
| 3 ..... | 5.30 | 3.03 | 2.27 | 0.040 | 0.378 | 0.068 | 0.025 |
| 4 ..... | 5.14 | 4.73 | 0.41 | 0.060 | 0.700 | 0.082 | 0.021 |

Oxide Analysis, Per Cent:

| Sample | $SiO_2$ | MnO | FeO | $Al_2O_3$ | Calcul'd $O_2$ |
|---|---|---|---|---|---|
| 1. Slow cooled | 0.0010 | nil | 0.0013 | 0.0017 | 0.0016 |
| 1. Chilled ... | 0.0031 | nil | 0.0016 | 0.0031 | 0.0035 |
| 2. Slow cooled | 0.0035 | nil | 0.0032 | 0.0035 | 0.0042 |
| 2. Chilled ... | 0.0026 | nil | 0.0015 | 0.0054 | 0.0042 |
| 3. Slow cooled | 0.0021 | nil | 0.0007 | 0.0013 | 0.0019 |
| 3. Chilled ... | 0.0047 | nil | 0.0018 | 0.0047 | 0.0051 |
| 4. Slow cooled | 0.0019 | nil | 0.0014 | 0.0039 | 0.0031 |
| 4. Chilled ... | 0.0030 | nil | 0.0030 | 0.0047 | 0.0045 |
| Aver. ..... | 0.0027 | nil | 0.0018 | 0.0035 | 0.0035 |

#### 5. Iron-Carbon-Sulphur Alloy.

Chemical Analysis, Per Cent:

| Sample | Total C | G.C. | C.C. | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| 1 ..... | 5.30 | 3.82 | 1.48 | 0.035 | 0.010 | 0.058 | 0.018 |
| 2 ..... | 5.26 | 3.88 | 1.38 | 0.035 | 0.009 | 0.076 | 0.016 |
| 3 ..... | 5.36 | 4.31 | 1.05 | 0.030 | 0.010 | 0.100 | 0.021 |

Chemical Analysis, Per Cent:

Oxide Analysis, Per Cent:

| Sample | $SiO_2$ | MnO | FeO | $Al_2O_3$ | Calcul'd $O_2$ |
|---|---|---|---|---|---|
| 1. Slow cooled | 0.0017 | nil | 0.0017 | 0.0050 | 0.0036 |
| 1. Chilled ... | 0.0014 | nil | 0.0034 | 0.0060 | 0.0043 |
| 2. Slow cooled | 0.0010 | nil | 0.0132 | 0.0036 | 0.0051 |
| 2. Chilled ... | 0.0017 | nil | 0.0067 | 0.0052 | 0.0048 |
| 3. Slow cooled | 0.0030 | 0.0001 | 0.0097 | 0.0042 | 0.0057 |
| 3. Chilled ... | 0.0008 | nil | 0.0084 | 0.0052 | 0.0047 |
| Aver. ..... | 0.0016 | nil | 0.0072 | 0.0049 | 0.0047 |

#### 6. Iron-Carbon-Silicon Alloy.

| Sample | Total C | G.C. | C.C. | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| 1. ..... | 4.59 | 3.51 | 1.08 | 0.040 | 0.010 | 0.037 | 0.81 |
| 2. ..... | 4.32 | 3.49 | 0.83 | 0.040 | 0.009 | 0.032 | 1.54 |
| 3. ..... | 5.94 | 4.81 | 1.13 | 0.050 | 0.009 | 0.025 | 2.44 |
| 4. ..... | 4.18 | 3.12 | 1.06 | 0.045 | 0.010 | 0.066 | 2.54 |

Oxide Analysis, Per Cent:

| Sample | $SiO_2$ | MnO | FeO | $Al_2O_3$ | Calcul'd $O_2$ |
|---|---|---|---|---|---|
| 1. Slow cooled | 0.0035 | nil | 0.0086 | 0.0044 | 0.0058 |
| 1. Chilled ... | 0.0061 | nil | 0.0008 | 0.0081 | 0.0082 |
| 2. Slow cooled | 0.0045 | 0.0006 | 0.0095 | 0.0072 | 0.0083 |
| 2. Chilled ... | 0.0050 | nil | 0.0017 | 0.0075 | 0.0066 |
| 3. Slow cooled | 0.0040 | nil | 0.0040 | 0.0030 | 0.0044 |
| 3. Chilled ... | 0.0063 | nil | 0.0055 | 0.0095 | 0.0089 |
| 4. Slow cooled | 0.0036 | nil | 0.0006 | 0.0073 | 0.0054 |
| 4. Chilled ... | 0.0022 | nil | 0.0080 | 0.0052 | 0.0054 |
| Aver. ..... | 0.0044 | nil | 0.0048 | 0.0065 | 0.0066 |

#### 7. Grades of Pig Iron.

Chemical Analysis, Per Cent:

| Sample | Total C | G.C. | C.C. | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| Bessemer ..... | 5.88 | 5.20 | 0.68 | 0.50 | 0.099 | 0.050 | 1.29 |
| L. P. Bessemer ..... | 4.86 | 4.35 | 0.51 | 0.51 | 0.034 | 0.048 | 1.31 |
| Basic ..... | 5.56 | 4.91 | 0.65 | 1.75 | 0.195 | 0.104 | 0.90 |
| Foundry ..... | 5.16 | 4.74 | 0.42 | 0.79 | 0.364 | 0.041 | 2.29 |
| Malleable .... | 5.21 | 3.66 | 1.55 | 0.50 | 0.153 | 0.060 | 0.90 |

Oxide Analysis, Per Cent:

| Sample | $SiO_2$ | MnO | FeO | $Al_2O_3$ | Calcul'd $O_2$ |
|---|---|---|---|---|---|
| Bessemer, Slow Cooled.. | 0.0015 | 0.0006 | 0.0014 | 0.0076 | 0.0048 |
| Bessemer, Chilled ..... | 0.0033 | nil | 0.0084 | 0.0047 | 0.0058 |
| Low P Bessemer | | | | | |
| Slow cooled..... | 0.0020 | 0.0011 | 0.0009 | 0.0056 | 0.0041 |
| Chilled ..... | 0.0076 | 0.0016 | 0.0015 | 0.0062 | 0.0076 |
| Basic, Slow cooled..... | 0.0033 | 0.0008 | 0.0039 | 0.0052 | 0.0052 |
| Basic, Chilled ..... | 0.0011 | nil | 0.0010 | 0.0042 | 0.0030 |
| Foundry, Slow Cooled.. | 0.0040 | 0.0003 | 0.0006 | 0.0041 | 0.0043 |
| Foundry, Chilled ..... | 0.0031 | nil | 0.0022 | 0.0059 | 0.0049 |
| Malleable, Slow Cooled. | 0.0020 | 0.0005 | 0.0006 | 0.0062 | 0.0041 |
| Malleable, Chilled ... . | 0.0013 | nil | 0.0018 | 0.0037 | 0.0028 |

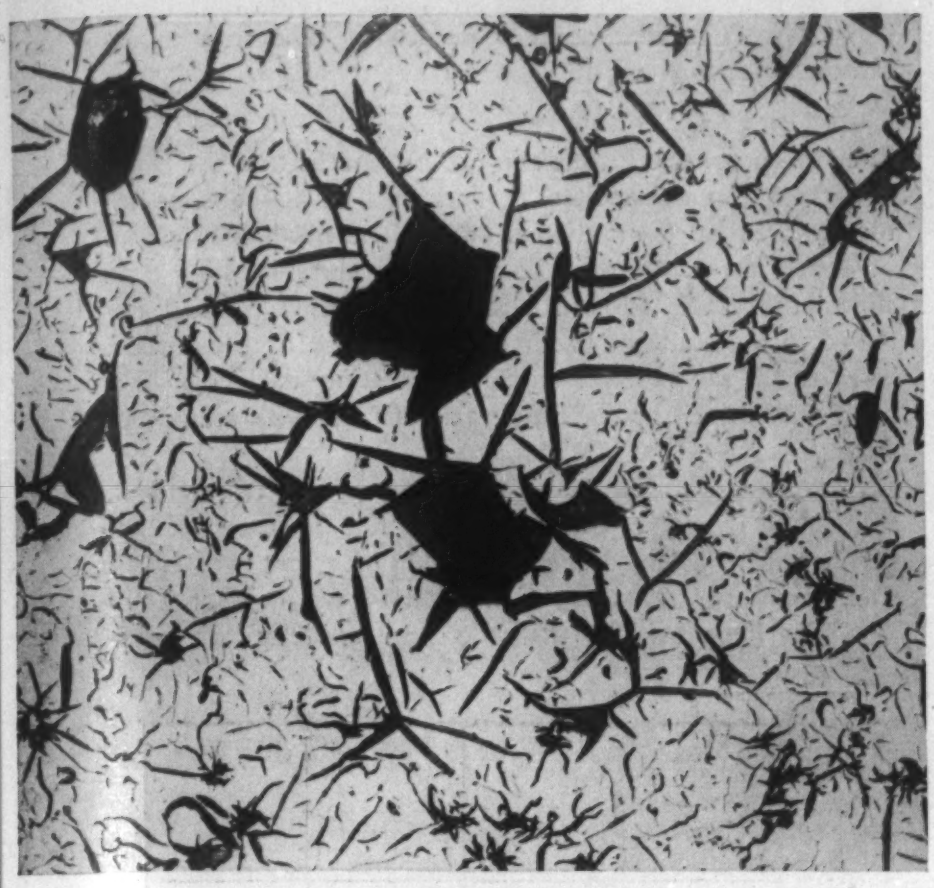


*Fig. 2. Large Silicate Inclusions. Unetched. 100 X.*

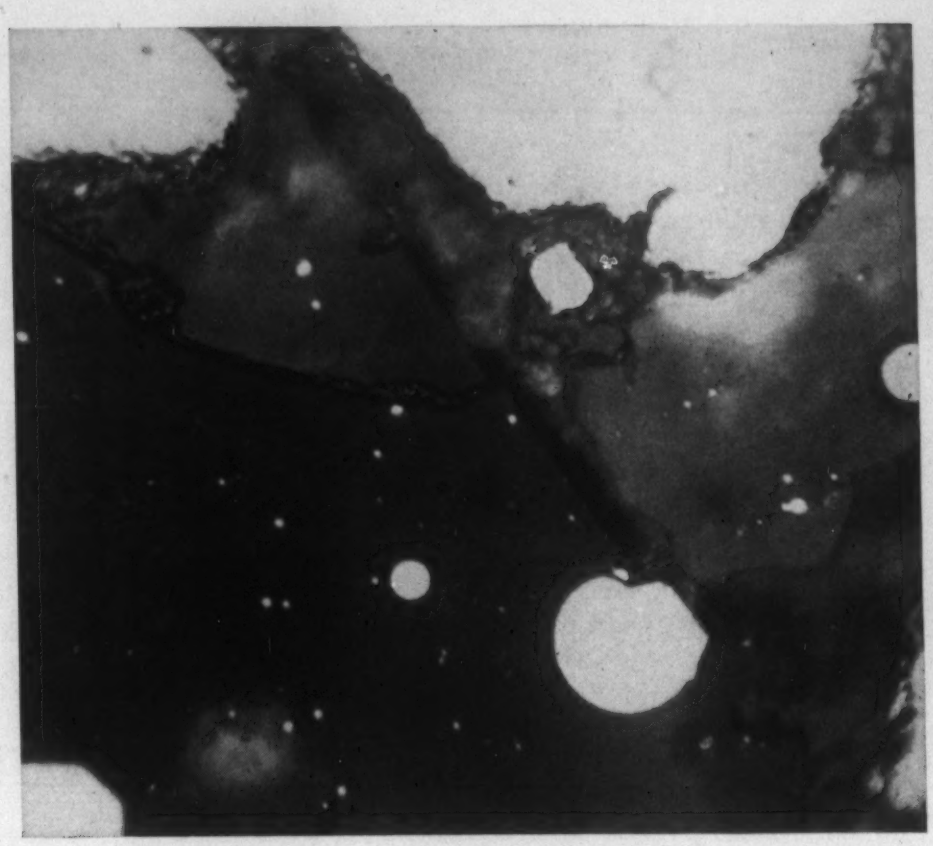


*Fig. 3. Large Silicate Inclusion Showing Entrapped Metallic Shots Inside the Inclusion. Unetched. 1000 X.*

of these pieces constituted the sample for oxide analysis.

The slow cooled cylindrical tests, 2 in. in diameter, and 2¼ in. in depth were sawed into two pieces at the center, and a slice ⅛ in. thick cut. The outer edge of this thin disc was cleaned of scale and graphite before extraction.

Drillings were prepared from the slow cooled sample, and these analyzed for total carbon, graphite, manganese, phosphorus, sulphur and silicon. In preparing the drillings for carbon analysis, special care was taken to obtain representative portions.

The chemical analysis of the low metalloid iron was made on drillings taken from four different pieces of iron selected at random from the lot. These pieces were different than those used for the oxide analysis, and no direct comparison may be made between them. The average should represent the material used in the preparation of the high carbon irons.

## SUMMARY

IN STUDYING the presence of iron and manganese oxides, and their siliceous compounds, in high carbon irons, it is desirable to know what will control their limits. It is known that in steels we have an equilibrium established between the dissolved carbon and the oxides of iron according to the equation;

$$C + FeO = Fe + CO$$

This reaction controls the elimination of carbon from the

*Fig. 4. Typical Inclusion. Unetched. 1000 X.*

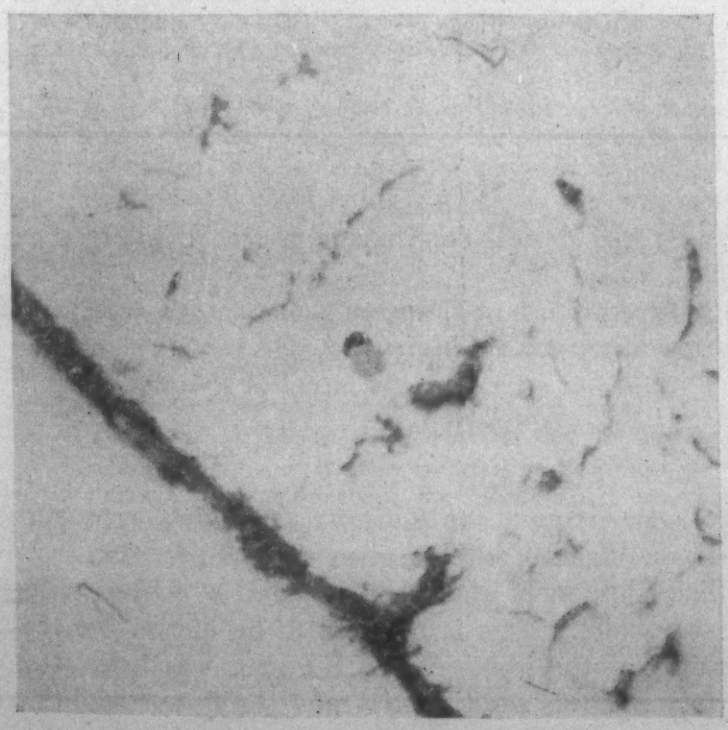
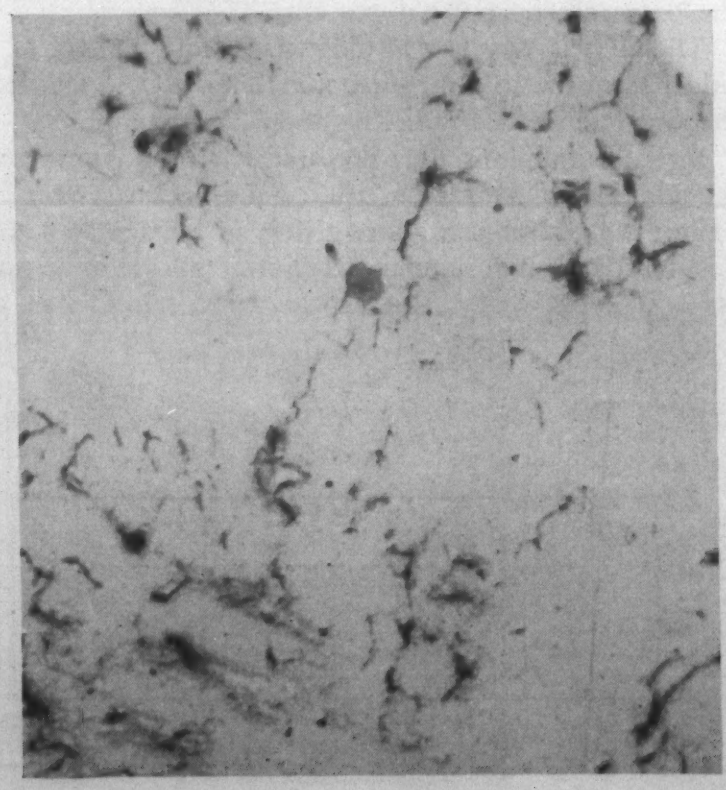


*Fig. 5. Typical Inclusion. Unetched. 1000 X.*



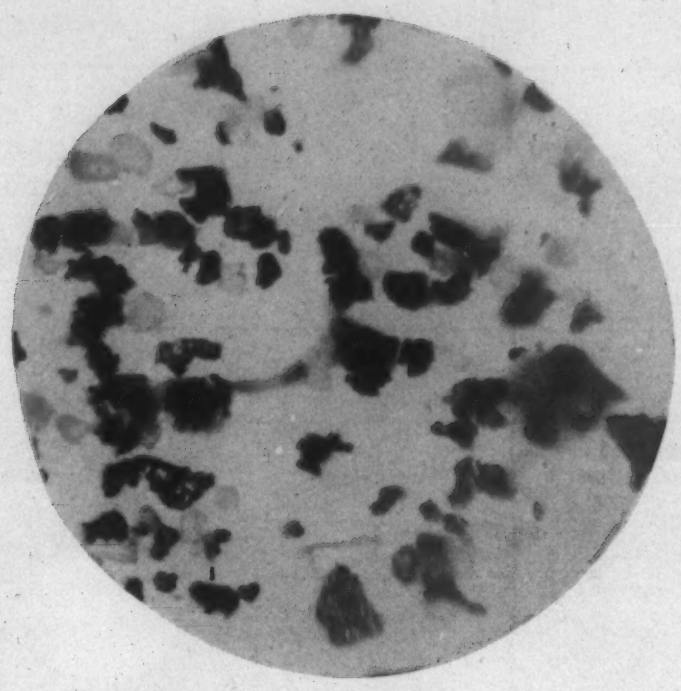


*Fig. 6. Silicate Residue. 100 X.*

bath during the working of the heat, and also makes possible the production of "rimmed" steel. It has been observed that in open-hearth steels the evolution of gas ceases when the product of the per cent of FeO and C is between 0.01 and 0.03. There is some doubt that this represents a true equilibrium, as Chipman[40] has calculated the equilibrium constant to be 0.005 at 1620 deg. C.

The results shown in the average analysis of the oxides in the low metalloid iron used in these experiments indicates that they are in good agreement with those expected from theoretical calculations. Considering the iron oxide-carbon product;

$$\text{Theoretical } \%\ FeO \times \%\ C = K = 0.005 \ (1620^\circ\ C.)$$
$$\text{Experimental } 0.1653 \times 0.033 = 0.0055$$

Considering the MnO, according to Chipman.

$$\text{Theoretical (MnO)} = 2.30 \times \%\ FeO \times \%\ Mn \ (1600^\circ)$$
$$= 2.30 \times 0.1653 \times 0.027$$
$$= 0.010 \text{ (mol fraction)}$$

The analysis of the slag inclusions shows that the mol fraction of MnO is 0.065. This may be due to the fact that some MnO is eliminated during ingot solidification as well as the fact that there is some slight solubility during the extraction and washing. However, the error is only of the order of about 0.004 per cent.

The $SiO_2$ is very low in the metal, and is present as residual from the silicon oxidation. The $Al_2O_3$ comes from the aluminum added to the ingot during teeming.

In the carbon-iron alloy prepared from the Armco iron, the addition of the carbon reduced the FeO to a very low figure; the carbon-iron alloys giving an average of 0.0077 per cent and the sulphur-carbon-iron alloys an average of 0.0072 per cent. The hypereutectic iron had an average carbon content of 5.25 per cent. The iron oxide-carbon product gives;

$$5.25 \times 0.0077 = 0.040$$
$$5.25 \times 0.0072 = 0.038$$

The reason for the increase in the product is that the higher carbon iron was melted at, and held at, a low temperature, 1500 deg. C., and it is known the product increases at lower temperatures. To illustrate this, in Fig. 8 is shown the values for the iron oxide—carbon product obtained in the study of the basic open-hearth by the author. The results are based on actual operation data, the FeO being determined by deoxidizing a bath test with aluminum metal.

According to Chipman's thermodynamic calculations, manganese is a poor deoxidizer. In the presence of 2.00 per cent Mn, as much FeO as 0.088 per cent will be in equilibrium at 1600 deg. C., or 0.044 per cent at 1500 deg. C. It is evident that the iron oxide-carbon equilibrium will control the amount of iron oxide in the high carbon iron.

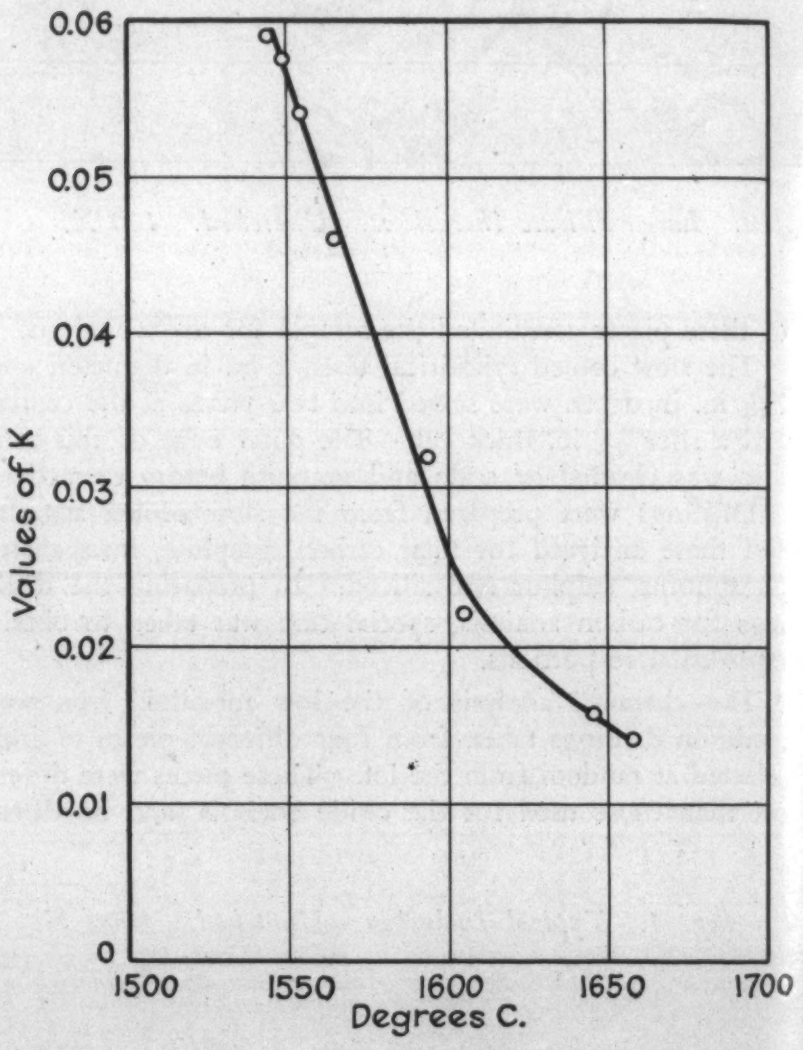



*Fig. 8. Relationship of FeO-C Product and Bath Temperature.*

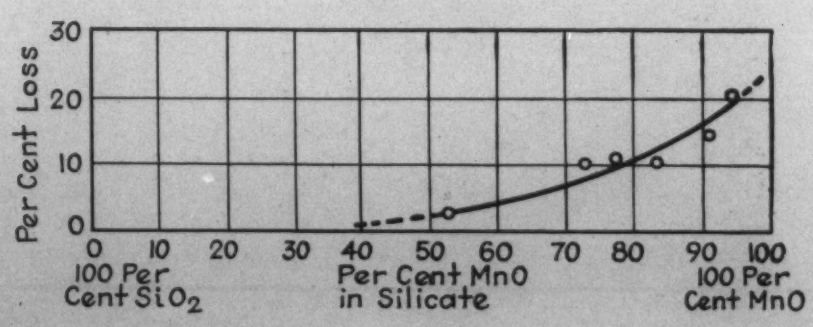
Again referring to Chipman's outstanding work, we find for the silicon-carbon-iron;

$$\text{Theoretical. } (\%\ FeO)^2 \times \%\ Si = 0.48 \times 10^{-4} \ (1600^\circ\ C.)$$
$$\text{Experimental. } (FeO)^2 = \frac{0.48 \times 10^{-4}}{2.50}$$
$$(FeO)^2 = 0.0019\%$$
$$FeO = 0.0045\%$$

The average result for the tests containing approximately this percentage of silicon gives 0.0045 per cent.

The addition of phosphorus caused a general reduction in the oxides. This is believed to be due to the reduced viscosity of the iron. When the melt was held after the ferrophosphorus addition, the molten slag was seen to come

*Fig. 7. Effect of Electrolytic Extraction on Manganous Silicates.*



to the surface, and was seen to be a dirty-yellowish-white, opaque glass upon cooling.

## Conclusion

Early work on the application of the electrolytic iodine method to deoxidized steels indicated that the results obtained compared favorably with the average of those reported by the vacuum fusion method. These oxygen figures indicated that only slight, if any, solution occurred during the extraction and washing of the oxides. The solubility of manganous silicate is indicated by the curve in Fig. 7. It can be seen that in the presence of silicon, when the manganous silicate is over 50 per cent $SiO_2$, the loss is negligible.

The extraction apparatus and materials were inexpensive, and although the method required considerable time, one man could make a number of determinations simultaneously. The oxide residue permitted isolation of the oxides for microscopic study, and also their complete chemical analysis. Fig. 6 shows a silicate residue, magnified 100 times, and indicates that such particles may be easily separated and studied by petrographic methods.

The work on high carbon irons indicates that it is as applicable to this material as to steels. Careful manipulation and analytical skill will assure good results within close limits of accuracy. It has been demonstrated that the metalloids do not cause high results, nor wide variations. Different rates of cooling do not cause any difficulty. It is possible to apply this method to the study of oxides in foundry iron with reasonable assurance of obtaining reproducible, comparative, and accurate results.

# EXTRACTION AND ANALYSIS OF OXIDES FROM HIGH CARBON IRON

THIS METHOD of oxide extraction has been published in detail, but subsequent work on hundreds of samples has led to a number of small changes and modifications that make it desirable to review the procedure briefly.

*Extraction Cell:* The construction of the cell, shown diagrammatically in Fig. 9, is simple and inexpensive. The cell consists of a large-mouthed 3-liter bottle lined with a copper screen cathode. Suspended in the center of the bottle is a glass tube. A hardened filter paper, which acts as a membrane, is fastened across the bottom of the glass tube. A small reagent bottle with bottom removed has been found convenient for use as the inner cell. The sample of iron is suspended in the inner cell by means of a platinum wire, and is the anode.

*The Electrolyte:* The electrolyte is a 5 per cent solution of magnesium iodide in which approximately 5 grams of iodine has been dissolved. This may be prepared by allowing 120 grams of iodine to react with magnesium metal until magnesium hydroxide appears and then filtering the solution. Dissolve 5 grams of iodine in the filtered solution and dilute to volume.

*Source of Power:* The source of power is an ordinary heavy-duty storage battery equipped with a charger. In this investigation 4 cells were operated simultaneously using 4 amp. per hr., which required that the charger supply the 4 amp. It should be so arranged that the charging rate can be varied according to the demand. Each extraction cell should have a variable resistance in the circuit so that the amperage can be controlled at 1 amp. At this rate about one gram of iron or steel will be decomposed each hour. The arrangement used during this investigation is shown in Fig. 10.

*Preparation of Sample:* It is desirable to extract a sample of at least 50 grams and up to 100 grams. More than this weight of sample causes the graphite and carbon to be so voluminous that filtering and washing are difficult. The extraction is aided by having a sample of large area for its weight. In this work the pieces of pig iron were about 4 in. long, 1 in. wide and ⅛ in. thick. After the samples are cut from the casting, the edges are filed and the sample is cleaned of all oil, grease and dirt, and then weighed. A platinum wire is attached to the sample and the upper portion, which will not be submerged in the electrolyte, must be waxed. The sample is then suspended in the inner cell and the electrolysis proceeds.

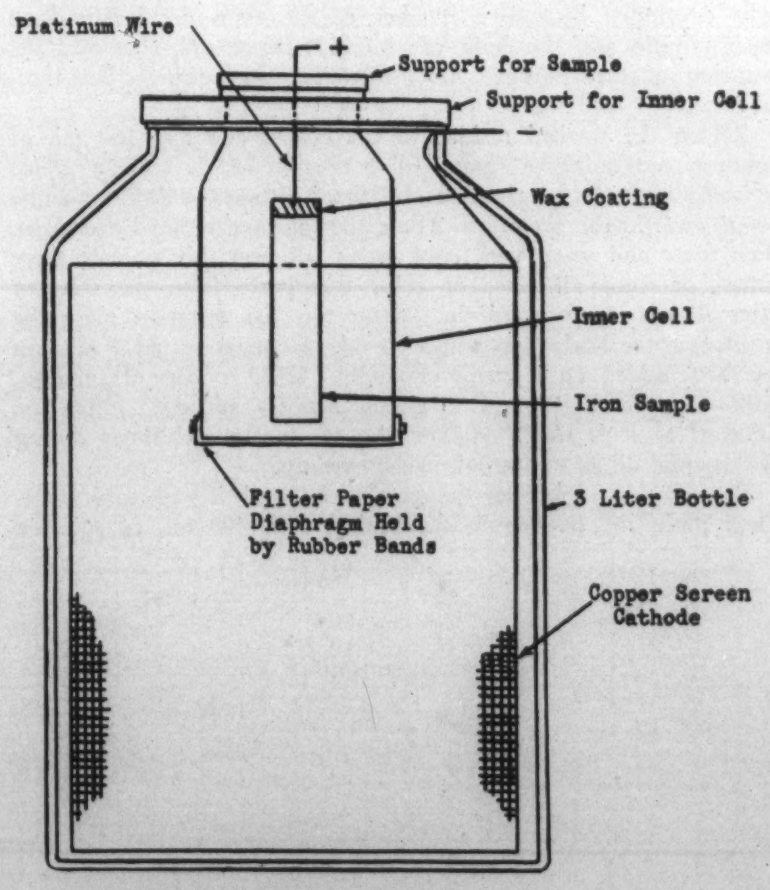
*Electrolysis:* At first the electrolysis will proceed rapidly, but as the area of the metal is reduced more voltage must be impressed to maintain the one ampere. Soon it will not be possible to keep so much amperage on the cell, but the electrolysis should proceed until the ammeter shows that all action has ceased. It is then ready to remove. The iron sample will retain its original shape and usually clings to the wire. It will be black and have a coating of iodine on the outside.

*Washing and Treatment of Residue:* Remove the sample from the jar by lifting out the platinum wire to which it is attached. Place in a casserole and gently remove the decomposed portion. If there is a core of undecomposed iron, scrape it clean with a spatula. Clean the stub and weigh. The weight of the sample is the difference between the weight when introduced into the cell and the weight of the stub. An inspection of the carbon skeleton will tell whether any has fallen off into the inner cell. If this has happened, filter the solution of the inner cell and add the recovered portion of the residue to that in the casserole.

In the extraction of pig iron, a considerable amount of iodine is plated out on the carbon skeleton. This, along with the ferrous iodide, magnesium iodide, and the silicic acid, must be removed by suitable washing. Any small particles of metallic iron also must be removed. The following scheme was adhered to in this investigation.

Moisten the residue in the casserole with a solution of 15 grams potassium iodide and 15 grams ammonium citrate in 50 ml. of water, then grind in a casserole with an agate pestle until all the carbon is very finely divided and the solution is a smooth slurry. This is very important, as the carbon has absorbed such a large amount of salts that a thorough washing can be accomplished only if there are no lumps. During the grinding

*Fig. 9. Sectional View of Electrolytic Cell.*



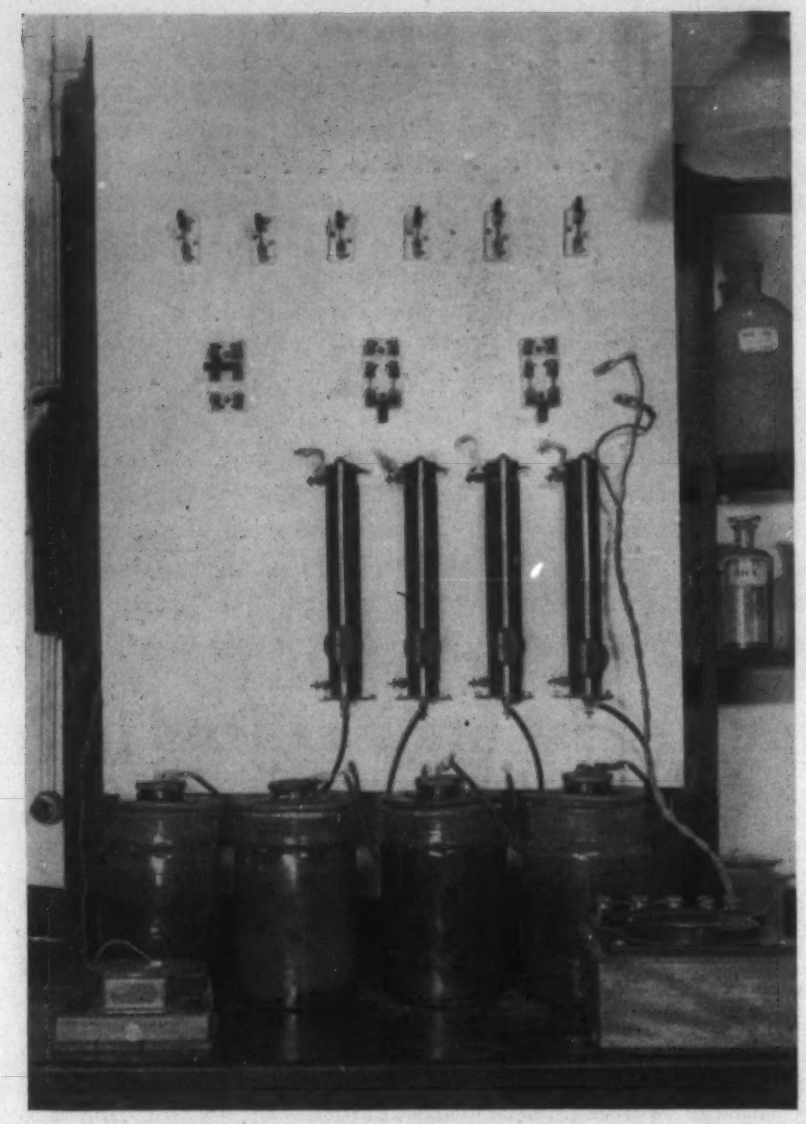


*Fig. 10. Arrangement of Electrolytic Cells and Control Board.*

the solution may be decanted into an 800-ml. beaker; the larger pieces remain in the casserole and are then ground. Often during this operation and decantation the oxides may be seen in the casserole and their types observed. When the grinding is complete, transfer all the residue to the beaker and dilute to 600 ml. Allow it to stand for 24 to 48 hours. Then filter the solution on a suction filter by means of a 45-mm., very retentive, ashless filter paper. In this work a special device, similar to a carbon tube, was developed because a number of filtrations are required on each sample and the bulk of the filter-paper pulp hampers the washing of the residue. After filtration, wash the residue thoroughly with cold water.

Return the washed residue to the beaker and add 100 ml. of solution containing 10 grams of potassium iodide and 20 grams of sodium citrate. Agitate several times during the day and dilute to 600 ml. in the evening. Allow the solution to stand overnight, then filter and wash with cold water. Repeat this at least three times, or until all trace of color disappears from the solution after it has stood overnight. After the last filtration place the residue in the beaker, to which 50 ml. of copper sulphate solution has been added (250 grams of $CuSO_4 . 5H_2O$ to liter of solution, with 1 gram MgO and 2 grams $MnCO_3$ added). Filter the solution as it is used. Agitate the residue several times during the day and dilute to 400 ml. in the evening.

The next morning filter the sample and wash it with cold water. Then place the residue in the beaker with 400 ml. of solution containing 15 grams of ammonium citrate. Warm about 30 minutes until the residue coagulates and settles to the bottom of the beaker. Filter and wash with hot water. Return the residue to the beaker, and add 400 ml. of solution containing 30 grams of sodium hydroxide and 30 grams of sodium tartrate. Warm gently for about 30 min. or until the residue coagulates and settles out; then filter, and wash thoroughly with hot water. Return the residue to the beaker, add 400 ml. of water containing 10 grams of ammonium citrate, and warm again for about 30 min. Filter with suction, and wash until the washings are colorless. Suck dry, and place the residue and paper pulp in a platinum dish or crucible. Dry and ignite. The residue will contain $SiO_2$, $Mn_3O_4$, $Fe_2O_3$, $Al_2O_3$, CaO, $TiO_2$, and perhaps some traces of $Cr_2O_3$.

*Analysis of Residue:* As most chemists prefer certain methods of analysis those used in this investigation will be sketched briefly;

1. After fusion with potassium bisulphate, the fusion was leached out in water and the $SiO_2$ dehydrated in sulphuric acid. The $SiO_2$ was determined by volatilization with hydrofluoric acid and the residue in the platinum crucible was fused with potassium bisulphate and added to the filtrate from the $SiO_2$.

2. The copper was removed as CuS and the filtrate containing the iron, manganese, aluminum and titanium was boiled down to 100 ml. and oxidized with a few crystals of ammonium persulphate.

3. The solution was aliquoted into two portions, of which one was used for the manganese determination and one for the iron and alumina determinations.

4. The manganese was determined by the usual arsenite titration after persulphate oxidation. The manganese was calculated to MnO.

5. The iron, manganese and titanium were separated from the aluminum by the usual alkali separation and the aluminum was determined as $AlPO_4$. The aluminum was calculated to $Al_2O_3$.

6. The iron and manganese were dissolved from the filter paper with hydrochloric acid. Then it was washed. It was then oxidized and the iron determined colorimetrically. The iron was calculated to FeO.

*Extraction of Steel Samples:* The extraction of the steel samples is the same as for the pig iron. The test pieces in this investigation were square. After the outside was cleaned of oxides, the platinum wire was then attached to the sample. The top of the specimen was given a protective coating of wax and the tip was submerged and electrolyzed.

After the steel was extracted, the oxide and carbon residues were found on the membrane paper. The entire contents of the inner cell must be filtered and added to the residue clinging to the rest of the sample.

The residue is washed in the same manner as the high carbon iron residue, except that the caustic wash and the following wash are eliminated, as there is no silicic acid present. The residue is analyzed by the method used for the high carbon residue.

## Acknowledgment

The author wishes to express his appreciation to Prof. T. L. Joseph, head of the department of metallurgy, University of Minnesota, for his helpful suggestions and assistance in the preparation of this paper. Also he wishes to thank Prof. R. L. Dowdell, department of metallography, for his encouragement during the course of this investigation.

## References

[39] "Oxides in Basic Pig Iron and in Basic Open Hearth Steel." *Am. Inst. Mining Met. Engrs. Tech. Pub.* No. 804, 1937.

[40] "Application of Thermodynamics to the Deoxidation of Liquid Steel." *Trans. Am. Soc. Steel Treating,* Vol. 22, May, 1934, pp. 385-435.

# PRODUCTION TRENDS OF

# American Alloy Steels

## AND OF ELECTRIC STEELS

by Edwin F. Cone

AN ATTEMPT IS MADE in this article to clarify the situation as to the data for the production of the alloy steels, of the alloy steel castings, and of the corrosion and heat resisting steels of the United States. The present status of the production of electric steel is also reviewed. The first attempt of this nature was an article in the July, 1937, issue of METALS AND ALLOYS, Vol. 8, page 191, entitled "Trends in Production of American Alloy Steels and of Electric Steels." The present article also includes the 1937 data with the aim of bringing the whole subject up to date.

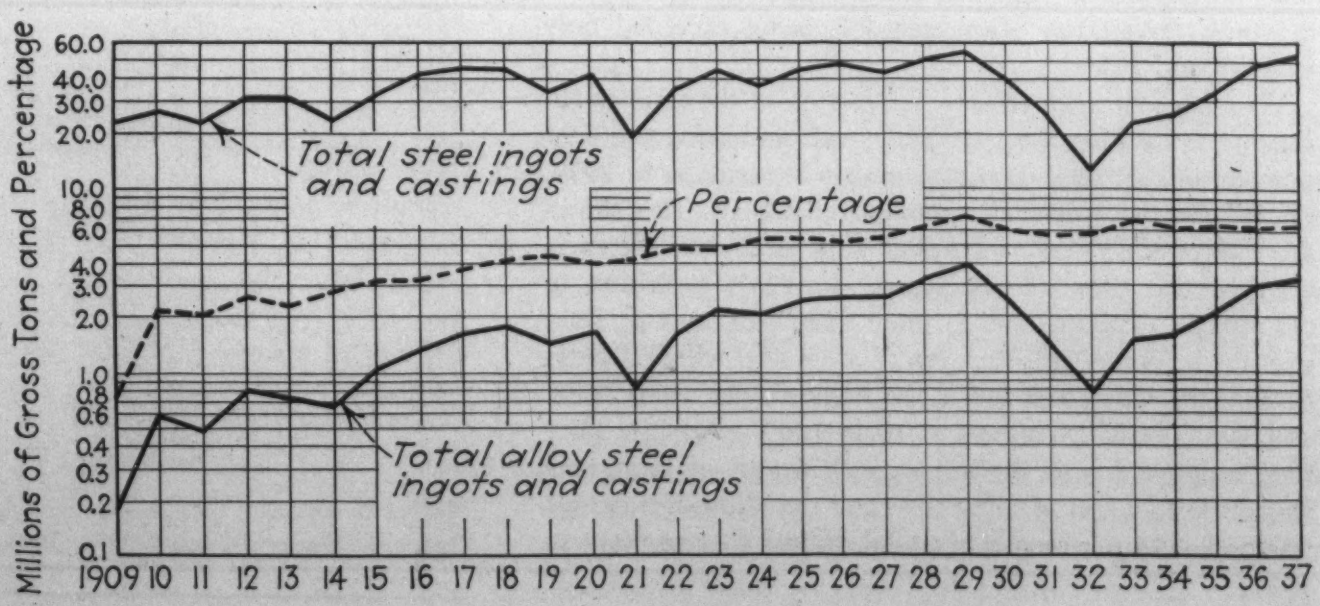
The clarification referred to seems to be necessary because the published data of the American Iron and Steel Institute, excellent and reliable as they are, are necessarily incomplete,—that is, they have been incomplete from 1934 to date, inclusive. The Institute's production data as to ingots is complete so far as such statistics can be. They are not complete as to steel castings, or rather, have not been since 1933. This is due to the establishing, under the NRA, of Codes of Fair Practice, to which were left the collection of data for certain types of steel castings. For example, the Steel Founders' Society of America collected, and still does, the production of miscellaneous and special commercial steel castings, the Alloy Casting Association assembles from its members the production of corrosion and heat resisting castings or so-called stainless steel castings, and the Manganese Steel Founders' Society obtains from its members the production of manganese alloy castings. Nowhere, however, are the total data of these several organizations assembled and published.

From as many data as were obtainable, an article, which shows the trend of the steel foundry industry in the last four years, was published in METALS AND ALLOYS, Vol. 9, July, 1938, page 178. This was made possible through the cooperation of the S. F. S. A.

### Total Alloy Steel

Keen interest centers in the progress of the advance in the output of alloy steels as a whole and of stainless steels in particular. In Table I are presented the data of the production of alloy steel ingots and castings in the United States in gross tons. To, and including 1933, the Institute's data include both ingots and castings, but from then on they represent largely only ingots, because of the founding of the codes discussed in a preceding paragraph.

It has been necessary, therefore, to modify the published data of the Institute for 1934, 1935, 1936 and 1937 by




*How the Proportion of Alloy Steel to the Total Steel Ingot and Castings Output Has Fluctuated in 29 Yrs.*

*Tapping a Heat of Stainless Steel from an Electric Furnace. (Courtesy: Allegheny Steel Co., Brackenridge, Pa.)*

including estimated additions of alloy steel casting production. These modified data appear in italics. On the advice of the S. F. S. A. the percentage of alloy steel castings of the total steel castings was approximately 14.5 per cent for 1934, 15.5 per cent for 1935 and 16.5 per cent for 1936. A figure of 15.5 per cent has been reliably fixed for 1937. On this basis the American steel casting production in gross tons (see METALS AND ALLOYS, Vol. 8, July, 1937, Table II, page 191) would be as follows:

| | Castings | Alloy | Alloy Per Cent |
|---|---|---|---|
| 1929 | 1,583,040 | 192,920 | 12.2 |
| 1930 | 1,104,215 | 126,128 | 11.5 |
| 1931 | 516,579 | 89,903 | 17.4 |
| 1931 | 216,760 | 41,044 | 18.8 |
| 1933 | 338,061 | 71,783 | 21.2 |
| 1934* | 425,000 | 61,625 | 14.5 |
| 1935* | 417,000 | 64,700 | 15.5 |
| 1936* | 812,500 | 134,000 | 16.5 |
| 1937* | 1,027,800 | 159,300 | 15.5 |

* Estimated.

Supplementing the published data of the American Iron and Steel Institute for 1937 and the three previous years, we obtain the statistics presented in Table I. It will be seen from these data that the total alloy steel ingot and castings output of the country in 1937 was 3,191,900 gross tons, an increase of 5.77 per cent over that of 1936. It is the third largest total ever recorded, being exceeded only in 1928 and 1929.

As related to the total steel production of the country for ingots and castings, the 1937 alloy steel production was 6.21 per cent of that total or approximately the same as in 1936. Of interest also is the last column of Table 1. This shows the tons of total steel to 1 ton of alloy steel since the early years of the alloy steel industry. In 1937, according to the revised estimated totals, there were 16.1 tons of total steel made in 1937 for each ton of alloy steel which slightly exceeds that for 1936 and is the highest since 1930, 1931 and 1932. Only 28 years ago, or in 1909, when the alloy steel industry was in its infancy, 131.6 tons of total steel was made to 1 ton of alloy steel and the alloy steel output was only 0.75 per cent of the total against 6.21 per cent in 1937.

**Table 1.—Production of Alloy Steel Ingots and Castings in United States—Gross Tons.**

| | Total Alloy Steel | Total Steel | Per Cent Alloy Steel | Tons of Total Steel to 1 Ton of Alloy Steel |
|---|---|---|---|---|
| 1909 | 181,980 | 23,955,021 | 0.75 | 131.6 |
| 1910 | 567,819 | 26,094,919 | 2.17 | 45.9 |
| 1911 | 481,459 | 23,676,106 | 2.03 | 49.1 |
| 1912 | 792,501 | 31,251,303 | 2.53 | 39.4 |
| 1913 | 714,357 | 31,300,874 | 2.28 | 43.8 |
| 1914 | 646,953 | 23,573,030 | 2.75 | 36.3 |
| 1915 | 1,021,147 | 32,151,036 | 3.17 | 31.4 |
| 1916 | 1,362,615 | 42,773,680 | 3.18 | 31.3 |
| 1917 | 1,644,335 | 45,060,607 | 3.65 | 27.4 |
| 1918 | 1,787,852 | 44,462,432 | 4.02 | 24.8 |
| 1919 | 1,481,188 | 34,671,232 | 4.27 | 23.4 |
| 1920 | 1,660,292 | 42,132,934 | 3.94 | 25.3 |
| 1921 | 809,548 | 19,783,797 | 4.10 | 24.3 |
| 1922 | 1,673,496 | 35,602,926 | 4.70 | 21.3 |
| 1923 | 2,106,489 | 44,943,696 | 4.70 | 21.3 |
| 1924 | 2,026,409 | 37,931,939 | 5.35 | 18.7 |
| 1925 | 2,432,973 | 45,393,524 | 5.36 | 18.6 |
| 1926 | 2,463,414 | 48,293,763 | 5.10 | 19.6 |
| 1927 | 2,531,748 | 44,935,185 | 5.59 | 17.7 |
| 1928 | 3,214,909 | 51,544,180 | 6.23 | 16.0 |
| 1929 | 3,957,207 | 56,433,473 | 7.01 | 14.2 |
| 1930 | 2,443,311 | 40,699,483 | 6.00 | 16.7 |
| 1931 | 1,455,913 | 25,945,501 | 5.61 | 17.8 |
| 1932 | 798,604 | 13,681,162 | 5.84 | 17.1 |
| 1933 | 1,547,183 | 23,232,347 | 6.65 | 15.0 |
| *1934* | *1,673,900* | *26,408,000* | *6.34* | *15.7* |
| *1935* | *2,184,300* | *34,438,000* | *6.35* | *15.7* |
| *1936* | *3,017,600* | *48,442,700* | *6.23* | *16.0* |
| *1937* | *3,191,900* | *51,421,900* | *6.21* | *16.1* |

## Electric Alloy Steel

Keen interest always centers in the electric steel industry's progress, both as to electric alloy steel produced and as to total electric steel made.

In Table 2 an attempt is made to supplement the data of the American Iron and Steel Institute for the last four years (1934 to 1937) by adding the estimated amount of electric alloy steel castings made by foundries which do not report to the Institute. It is reliably calculated that about 66 per cent of the alloy steel castings is produced in electric furnaces. Thus in 1937 there were 845,537 gross tons of electric steel ingots and some castings made as reported by the Institute. To this therefore must be added 66 per cent of the 159,300 tons of alloy steel castings, as discussed in the early part of this article, made in 1937 which brings the total electric alloy steel to 950,600 gross tons.

From Table 2 it is also interesting to note that the percentage of electric alloy steel of the total alloy steel produced reached the highest recorded figure during the last four years—22.7, 26.7, 28.5 and 29.7 per cent, with the

**Table 2.—Production of Alloy Steels made in Electric Furnaces in United States—Gross Tons.**

| | Electric | Total Alloy Steel | Per Cent of Electric Alloy Steel of Total Alloy |
|---|---|---|---|
| 1909 | ..... | 181,980 | .... |
| 1910 | 608 | 567,819 | 0.11 |
| 1911 | ..... | 481,459 | .... |
| 1912 | 9,619 | 792,501 | 1.21 |
| 1913 | 11,264 | 714,357 | 1.57 |
| 1914 | 9,344 | 646,953 | 1.44 |
| 1915 | 27,944 | 1,021,147 | 2.73 |
| 1916 | 71,129 | 1,362,615 | 5.22 |
| 1917 | 130,578 | 1,644,335 | 7.94 |
| 1918 | 290,961 | 1,787,852 | 16.26 |
| 1919 | 181,632 | 1,481,188 | 12.26 |
| 1920 | 245,572 | 1,660,292 | 14.78 |
| 1921 | 63,246 | 809,548 | 7.81 |
| 1922 | 125,419 | 1,673,496 | 7.49 |
| 1923 | 194,976 | 2,106,489 | 9.25 |
| 1924 | 188,563 | 2,026,409 | 9.30 |
| 1925 | 293,780 | 2,432,973 | 12.00 |
| 1926 | 306,811 | 2,463,414 | 12.45 |
| 1927 | 343,517 | 2,531,748 | 13.57 |
| 1928 | 433,096 | 3,214,909 | 13.47 |
| 1929 | 510,030 | 3,957,207 | 12.87 |
| 1930 | 300,520 | 2,443,311 | 12.51 |
| 1931 | 232,113 | 1,455,913 | 15.94 |
| 1932 | 140,877 | 798,604 | 17.65 |
| 1933 | 296,210 | 1,547,183 | 19.11 |
| *1934* | *401,900* | *1,673,900* | *22.7* |
| *1935* | *584,200* | *2,184,300* | *26.7* |
| *1936* | *860,900* | *3,017,600* | *28.5* |
| *1937* | *950,600* | *3,191,900* | *29.7* |

**Table 3.—Total Electric Steel Output**

| | Ingots | Castings | Total | Total Steel | Electric Per Cent |
|---|---|---|---|---|---|
| 1937 | 814,300 | 308,340 [1] | 1,122,650 | 51,421,901 | 2.37 |
| 1936 | 704,213 | 235,600 [2] | 939,800 | 48,442,000 | 1.94 |
| 1935 | 521,818 | 171,200 [3] | 693,000 | 34,438,800 | 2.01 |
| 1934 | 349,095 | 136,000 [4] | 485,000 | 26,417,600 | 1.83 |
| 1933 | 299,808 | 121,395 | 421,203 | 23,232,347 | 1.81 |
| 1929 | 532,392 | 419,039 | 951,431 | 56,433,473 | 1.68 |

[1] 30% of 1,027,800. [2] 29% of 812,500. [3] 41% of 417,600. [4] 32% of 425,000.

peak in 1937. One explanation of this is probably in increased demand for the high Cr and Cr-Ni steels.

Decidedly substantial progress, from the tonnage standpoint, was made in 1937 in the electric steel industry as a whole. Here also no actual data are available in published statistics since 1933. The American Iron and Steel Institute publishes the electric steel ingot output. Therefore taking the latter and adding to it the estimated electric steel casting production for the last four years, Table 3 is obtained. This is based on an estimate for the percentage of steel castings of the total steel casting production at 20 per cent in 1934, at 41 per cent in 1935, 32 per cent in 1936, and at 30 per cent in 1937.

## Total Electric Steel

From the data in Table 3 it is evident that the progress of the recovery in electric steel production was marked in 1937. The percentage of the electric steel output of the country's total steel was 2.37 per cent, the highest ever recorded. This contrasts with a previous high of 2.01 per cent in 1935.

Attention should also be called to the high total of electric steel ingots—814,310 gross tons last year. This is a new high and contrasts with 704,213 tons in 1936 and with only 532,392 in the boom year of 1929. This is partly explained by the increased demand for rolled products of corrosion and heat-resisting steels.

## The Stainless Steel Output

As to the progress in the production of the corrosion and heat-resisting steels, data for 1937 for steel ingots of these steels as published by the American Iron and Steel Institute are believed to be more representative as to completeness than ever before. In Table 4 are presented the data for the output of these steels in the last four years.

**Table 4—Production of Corrosion and Heat Resisting Alloy Starts—Gross Tons**

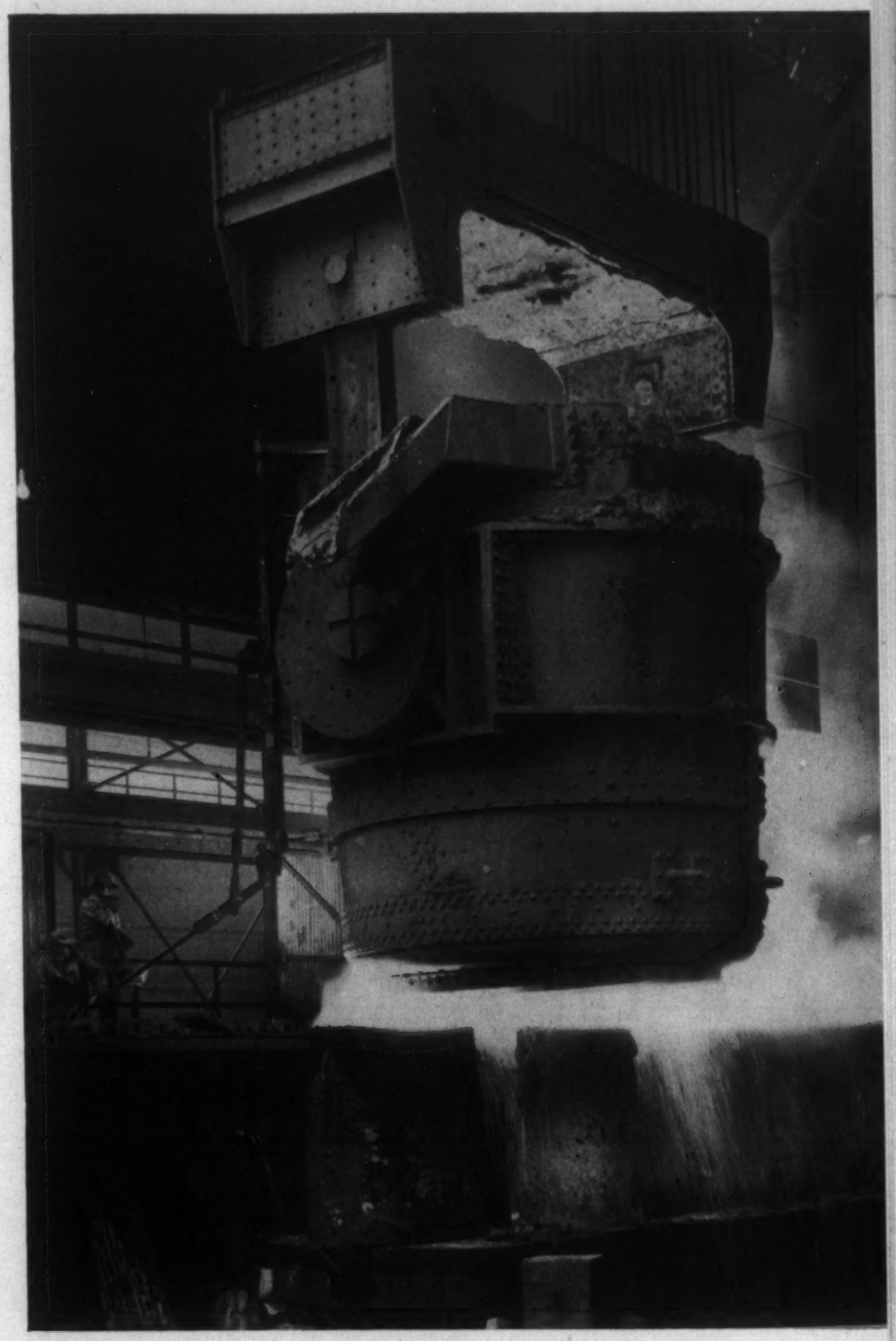
| | Ingots * | Castings ** |
|---|---|---|
| 1934 | 49,917 | 3,500 |
| 1935 | 65,697 | 3,800 |
| 1936 | 90,966 | 5,000 |
| 1937 | 139,834 | 7,500 |

* A. I. & S. Institute data.
** Estimated.

It will be noted that there has been an increase in the ingot output of these steels of 53.7 per cent in 1937 over 1936. This is not believed to be actual, but to be due to more complete data furnished the Institute in 1937. In any event, the data reflect the increased interest in and demand for the stainless steels.

## Summary

Recapitulating the data here discussed, some of it necessarily estimated but probably reliable as to trends, the following facts are prominent:



*A Large Proportion of the Alloy Steel Output of the Country is Made in Open-Hearth Furnaces. (Courtesy: Climax Molybdenum Co., New York.)*

*The trend in American alloy steel production is steadily upward.*

*Total estimated alloy steel output in 1937 of about 3,191,900 gross tons reveals an increase of 5.77 per cent over 1936 and is the third largest on record. It was 6.21 per cent of the total steel output or about the same as in 1936.*

*In an electric alloy steel a new record was made in 1937 at 950,600 gross tons (estimated). This compares with 860,900 tons in 1936 according to revised data for 1936. The percentage of electric alloy steel of the total alloy steel produced was 29.7 per cent in 1937—a new high. The increased percentage in the last four years is noteworthy.*

*New totals were made in the production of the corrosion and heat-resisting steels last year.*

It should be emphasized that the data here discussed are all based on the definition of an alloy steel as adopted by the Institute and under which the data are collected. Undoubtedly if this definition were revised, as it should be, the results would be considerably different.

# A Chuckle

## Carbide-Forming Elements Long Available

*To the Editor:* For your inspection a note from a somewhat eccentric acquaintance is subjoined. He requests me not to divulge his name; this is probably merely further evidence of eccentricity.

J. S. MARSH.

It is the purpose of this communication to demonstrate that the basic facts concerning the stabilization of 18-8 by the addition of carbide-forming elements have been freely available for many centuries. By inference it will be shown that these facts have been submerged unnecessarily by the recent spate of metallurgical research. The elements to be considered are titanium, columbium (or niobium), tantalum, vanadium, and molybdenum.

1. Titanium is chemists' jargon for *Titan,* one of a race of giants that warred unsuccessfully against the gods of Olympus. The defeat is of no consequence; carbon is no deity, therefore kidnaping such a lowly fellow is but child's play to him.

2. Vanadium is jargon for *Vanadis* (an alias of Freya), the Norse goddess of love and beauty. One of her stints is to entertain warriors fallen in battle, consequently she is too busy at promoting coziness to be a conscientious worker.

3. Tantalum, or *Tantalus,* won parental wrath by talking too much. By way of reprisal, he was water quenched up to the neck. Luscious, fragrant fruit hung just above his head, but every time he tried sampling, the fruit moved away. Inasmuch as fruit is carbonaceous, the prognosis is decidedly unfavorable.

4. Niobium, or *Niobe,* the daughter of Tantalus, inherited his penchant for peccadillos. Her ultimate conviction for feminine indiscretion was upheld by the highest court (Zeus, Presiding Justice), and she was duly turned to stone. It is obvious that, no matter how lush to the eye, a petrified goddess is a worker of minimum efficiency. This possibly will be learned in time by the Germans. At all events, they do not realize that by the simple artifice of changing her name to *Columbia,* she is free to roam at will. Her one fault, albeit useful, is dipsomania; happily for 18-8, she prefers her carbon neat.

5. Molybdenum, or *molybdos,* is plain, ungodlike lead, therefore hopelessly outclassed. The man of the mill, however, with intuitive wisdom, calls it *moly.* In so doing he converts this earthbound substance to a plant of magic virtues and the virtues of magic virtues are so widely appreciated that comment is unnecessary.

In fine, the useful stabilizers are clearly columbium (*not* niobium), titanium, and moly (*not* molybdenum). It may be deduced that moly additions will be expensive, because of the usual surcharge for magic.

Thus, much expensive research could have been avoided by making the fullest use of data already at hand.

# A Letter to the Editor

## Educational Ratios of Numbers and Extents

*To the Editor:* Any discussions pertaining to degraded educational systems, such as we are asked to believe exist today, are of vital interest, as well as a challenge, to the younger scientist, inasmuch as any instructional deterioration involves him directly, from the standpoints of (1) inadequacy of modern educational procedures, (2) decreased capability of present-day youth, and (3) a general "philosophical" disintegration of civilization. As a matter of major concern, the first item would naturally appeal to the younger scientist, the second to the older scientist, and the third, though often a subject of private academic discourse, to the lay populace.

Without wishing to enter into any controversy regarding "Who Killed Cock Robin?", or even agreeing that Cock Robin has been done away with at all, the writer would like to point out that even though it appears as if our present educational programs fail to transmit the newer principles and concepts to the future citizens of the world *in toto,* there are a greater number of eminent[1] scientists per capita today than in past history. One has only to examine a scientific "Who's Who" to convince oneself that, with such a record of accomplishment, civilization need not spend sleepless nights awaiting its death rattle.

It would seem that there are two main paths open to *homo sapiens*—following the one (A), he would repress research in pure and applied science (exclusive of educational processes) until he had perfected a procedure for distributing *all* knowledge equally to every fellow human, and had taken the time to see that every man knew as much as every other man, and that each knew all there was to know; in the meantime, there would be no improvement in the electron tube, the metallurgical process, the rate of growth of plants, the cure of human diseases, etc. Pursuing the other lane (B), which is suspiciously like the present course of human progress, he would endeavor to keep two ratios constant: (1) the ratio of the number of eminent scientists (including teachers, for the two should be interchangeable) to the total population, and (2) the ratio of the extent of knowledge, specialized and general, of the same parties. These ratios might obviously be other than those existent at present, but probably would not be greatly different[2].

It is apparent that if we followed the first path (A), our research personnel would have to be "drafted" into teaching positions. This could only be done under the stimuli of (a) increased salary, or (b) a force of some nature. If the former requirement were followed, (a), the money must come from an increased taxation of either (i) industry, or (ii) labor, either of which could easily lead to revolt. If stimulus (b) were instituted, the one who would be taught would have to assume the role of "police." In that event, we would have the strange case of the "oppressed" being also the "oppressor."

Should the alternative procedure (B) be adopted, the only adjustment necessary would probably be a gradually increased opportunity for promising students, i.e., the "naturals," to carry their studies into higher institutions of learning, and, ultimately, to an intelligent, directed research—the *Mecca* of Science[3].

It would appear that such a program could stabilized the optimum ratios of *numbers* and *extents* in the minimum of time.

MIKE A. MILLER.

New Kensington, Pa.
July 1, 1938

[1]The "degree of eminency" is probably higher today than ever before, if based on the ratio of the contributions of "eminent" scientists to the total contributions of other scientists, in most of the fields of endeavor. On the other hand, modern advances are more often based on group contributions, and hence cannot be uniquely evaluated.

[2]Symbolically, we can write:
$\frac{N_e}{N} = \frac{k}{E}; \frac{E_e}{E} = \frac{k'}{E}; \frac{N_e E}{N E_e} = \frac{k}{k'} = K$; where N and $N_e$ refer to the total population and to the number of "eminent" scientists, respectively, E and $E_e$ to the total knowledge of the same parties, and k, k', and K are constants. Then for situation (A): $N_e = N$; $E_e = E$ and $k = k' = K = 1$. For situation (B), k and k' will in general be much greater than one, and K need not necessarily be unity.

[3]In the industrial laboratory, the research worker must perforce produce "useful" results; these must be turned into processes and products, sometimes many years later, which are sufficiently remunerative to pay for the cost of the research materials, the worker's pay, and the interest on the investment. In an academic laboratory, particularly when the young worker is involved in the intricacies of a doctoral research, the head of the laboratory or department, unconsciously or otherwise, may tend to direct the student into those researches which fit best the director's program. Each unit has its good points and its bad points; it is the duty, and the destiny, of future generations to increase the one and destroy the other.